Feasibility Study

Waukegan Manufactured Gas and Coke Plant Site
Waukegan, Illinois

Prepared for North Shore Gas Company and General Motors Corporation

Under the Administrative Order on Consent Re: Remedial Investigation and Feasibility Study for the Waukegan Manufactured Gas and Coke Plant Site Waukegan, Illinois

U.S. EPA Docket No. 05-78-0005

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Table of Contents

List of Tables

List of Tables (cont.)

List of Figures

List of Figures (cont.)

List of Appendices

List of Abbreviations

4AAP	4-aminoantipyrene
ACL	Alternate Concentration Limits
AGQS	Alternate Groundwater Quality Standards
ANL	Argonne National Laboratories
AOC	Area of Contamination
ARAR	Applicable or Relevant and Appropriate Requirement
BDAT	Best Demonstrated Available Technology
BOD	Biochemical Oxygen Demand
BTEX	Benzene Toluene Ethylbenzene Xylene
CAA	Clean Air Act
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act of 1980
CFR	Code of Federal Regulations
COC	Constituent of Concern
COD	Chemical Oxygen Demand
CONTRA	Computer Transport Model
cPAH	Carcinogenic Polynuclear Aromatic Hydrocarbon
cm/s	centimeters per second
CTE	Central Tendency Exposure
CWA	Clear Water Act
CY	cubic yards
DNAPL	Dense Nonaqueous Phase Liquid
DO	Dissolved Oxygen
DOC	Dissolved Organic Carbon
ED	Exposure Duration
EEI	Edison Electric Institute
EF	Exposure Frequency
EPRI	Electric Power Research Institute
ERA	Ecological Risk Assessment
FAWQC	Federal Ambient Water Quality Criteria
FS	Feasibility Study
FSP	Field Sampling Plan
ft/sec	feet per second
GC/MS	Gas Chromatograph/Mass Spectrometer
GLI	Great Lakes Initiative
GMZ	Groundwater Management Zone
gpm	gallons per minute
GQS	Groundwater Quality Standards
HA	Health Advisory
HDPE	High Density Polyethylene
HHRA	Human Health Risk Assessment
HI	Hazard Index
IAC	Illinois Administrative Code
IEPA	Illinois Environmental Protection Agency
IPCB	Illinois Pollution Control Board
IR	Inhalation Rate
IWQS	Illinois Water Quality Standards
LDR	Land Disposal Restrictions
LS	Lump Sum
LREL	Lowest Reported Effects Levels
m/sec	meters per second
MCL	Maximum Contaminant Level

List of Abbreviations (cont.)

MCLG	Maximum Contaminant Level Goal
MGP	Manufactured Gas Plant
mg/kg	milligram per kilogram
mg/L	milligram per liter
µg/L	micrograms per liter
µg/m^3	micrograms per cubic meter
MW	Monitoring Well
MSL	Mean Sea Level
NCP	National Contingency Plan
NPDES	National Pollutant Discharge Elimination System
NSG	North Shore Gas
OC	On Center
OMC	Outboard Marine Corporation
OSHA	Occupational Safety and Health Act
OSWER	Office of Solid Waste and Emergency Response
PAH	Polynuclear Aromatic Hydrocarbon
PCB	Polychlorinated Biphenyl
PCP	Pentachlorophenol
PEF	Particulate Emission Factor
PHSP	Project Health & Safety Plan
PNA	Polynuclear Aromatic Hydrocarbon
POTW	Publicly-Owned Treatment Works
ppm	parts per million
PRG	Preliminary Remediation Goal
PSCS	Preliminary Site Characterization Summary
PW	Pumping Well
QAPP	Quality Assurance Project Plan
RAGS	Risk Assessment Guidance for Superfund
RAO	Remedial Action Objective
RCRA	Resource Conservation and Recovery Act
REC	Representative Exposure Concentration
RHE	Representative High Exposure
RI	Remedial Investigation
RI/FS	Remedial Investigation/Feasibility Study
RME	Reasonable Maximum Exposure
ROD	Record of Decision
SARA	Superfund Amendments and Reauthorization Act
SB	Soil Boring
SDWA	Safe Drinking Water Act
SF	Square Foot
SI	Site Investigation
SLAEM	Single Layer Analytic Element Model
SMCL	Secondary Maximum Contaminant Level
TACO	Tiered Approach to Corrective Action Objectives
TBC	To Be Considered
TCLP	Toxicity Characteristic Leaching Procedure
TI	Technical Impracticability
TKN	Total Kjeldahl Nitrogen
TM	Technical Memorandum
TOC	Total Organic Carbon
tPAH	Total PAH

List of Abbreviations (cont.)

TSC	Target Soil Concentrations
TSCA	Toxic Substances Control Act
TT	Test Trench
UCL	Upper Confidence Limit
USACE	United States Army Corps of Engineers
U.S. EPA	United States Environmental Protection Agency
VF	Volatilization Factor
VOC	Volatile Organic Compound
WCP	Waukegan Manufactured Gas and Coke Plant
WP	Work Plan

Executive Summary

The Waukegan Manufactured Gas and Coke Plant (WCP) site is located in Waukegan, Illinois, on the peninsula separating Waukegan Harbor (the harbor) from Lake Michigan (the lake). The plant was built in 1928, operated through 1969 and was demolished in 1972. The property and its environs have been and will continue to be part of the industrial/commercial waterfront in Waukegan. The sand dunes/beach area adjacent to the WCP site is used for public recreation.

The soil and groundwater quality at the WCP site has been adversely impacted due to past activities. Soil at the WCP site is contaminated with tar and arsenic. Tar contamination occurs in discrete deposits in the eastern and southern part of the site. Arsenic soil contamination is most prevalent at one location in the eastern part of the site; lesser concentrations of arsenic occur along the eastern half of the site. Groundwater contamination occurs sporadically throughout the sand aquifer, although the more significant contamination is located in the lowest 5 feet of the sand aquifer, approximately 25 feet below ground surface. The impacted groundwater has elevated concentrations of arsenic, phenols, and ammonia.

Upon a thorough screening of a wide spectrum of in-situ and ex-situ remedial alternatives, four combined alternatives were selected for detailed analyses and subjected to evaluation under the seven National Contingency Plan (NCP) criteria. These are:

Remedial Alternative 1: No Action is the absence of any remedial actions. No action is considered in this evaluation as a baseline for comparison to all other potential remedial actions, as required by the NCP.

Remedial Alternative 2: Containment consists of:

Vadose Zone Soil Remedial Components

- Excavation of PAH Remediation Zone soil and treatment by power plant co-burning or equivalent process (Alternative 2A)
- Stabilization/solidification of Arsenic Remediation Zone soil (Alternative 2A)
- Asphalt cap for Marginal Zone soil

- Land development restrictions to protect the integrity of the cap, the slurry wall, and the associated storm-water detention basin

Variations of these alternatives include Alternative 2B which includes disposal of PAH and Arsenic Remediation Zone soil at a RCRA Subtitle C or D landfill and Alternative 2C which includes constructing an on-site containment unit for PAH and Arsenic Remediation Zone soil

Groundwater Remedial Components

- Containment system on the eastern portion of the site, consisting of a slurry wall system, and interior extraction/drainage units
- Treatment cells on beach and harbor with reinjection in cells. Ex-situ treatment includes the removal of arsenic, phenols, organics, and ammonia.
- Monitored natural attenuation
- Infiltration reduction in areas capped with the asphalt cap, and the lined storm-water detention basin
- Institutional controls to prevent installation of potable wells

Remedial Alternative 3: Removal consists of:

Vadose Zone Soil Remedial Components

- Excavation of PAH Remediation Zone soil and treatment by power plant co-burning or equivalent process (Alternative 3A)
- Stabilization/solidification of Arsenic Remediation Zone soil (Alternative 3A)
- Phytoremediation cap for Marginal Zone soil, and the backfilled excavation areas
- Development of institutional controls and a post-remedy soil management plan

Variations of these alternatives include Alternative 3B which includes disposal of PAH and Arsenic Remediation Zone soil at a RCRA Subtitle C or D landfill.

Groundwater Remedial Components

- Treatment cells on beach and harbor with reinjection in cells. Ex-situ treatment includes the removal of arsenic, phenols, organics, and ammonia.
- Monitored natural attenuation
- Infiltration reduction through combined phytoremediation/asphalt/building cap
- Institutional controls to prevent installation of potable wells

Remedial Alternative 4: Aquifer Restoration consists of:

Vadose Zone Soil Remedial Components

- Excavation of PAH Remediation Zone soil and treatment by power plant co-burning or equivalent process
- Stabilization/solidification of Arsenic Remediation Zone soil
- Disposal at a RCRA Subtitle D landfill for Marginal Zone soil

Groundwater Remedial Components

- Groundwater extraction at 200 gpm from wells located along the hydraulic divide. Ex-situ treatment includes the removal of arsenic, phenols, organics, ammonia, and cyanide prior to discharge to (NSSD). The groundwater remediation goal is restoration of the aquifer to drinking water standards.

The above four Remedial Alternatives are evaluated in accordance of the seven NCP criteria (USEPA, 1988b). The summary results of this comparative analysis are given below:

1. ***Protection of Human Health and the Environment***: The No Action alternative is not protective of human health and the environment, while Remedial Alternatives 2, 3, and 4 are protective of human health and the environment throughout their life spans. These remedies would eliminate direct contact to contaminated soil and minimize the migration of contaminants from soil via groundwater to surface water. The protectiveness of these alternatives would be ensured through institutional controls to restrict on-site groundwater use.

2. ***Compliance with ARARs***: The No Action alternative does not meet ARARs due to unacceptable surface soil exposures. Remedial Alternative 2 and 3, on the other hand, meet ARARs, with

active groundwater remedies designed to protect the surface water. The technical impracticability of groundwater restoration (Remedial Alternative 4) may require the waiver of drinking water standards ARARs.

3. ***Long-Term Effectiveness and Permanence***: The No Action alternative is currently non-protective and could prolong the recovery of the site. Remedial Alternative 2, 3, and 4, aim at removing and capping PAH- and arsenic-impacted soils. Remedial Alternative 3, however, includes the added remedial benefits of an extensive phytoremediation cap, which further enhances the long-term effectiveness and permanence of this remedy. Concerning groundwater remedies, Remedial Alternatives 2, 3, and 4 include contaminant removal and flux reduction. Given the technical impracticability of attaining drinking water standards under Remedial Alternative 4, all these alternatives provide equivalent long-term effectiveness and permanence.

4. ***Reduction of Toxicity, Mobility or Volume through Treatment***: The No Action alternative would rely on unenhanced natural attenuation processes to reduce toxicity, mobility, and volume. Remedial Alternative 2, 3, and 4 reduce the volume of contaminants through treatment of soil and groundwater. Alternative 3 reduces mobility of soil contaminants with the phytoremediation cap. Given the diminishing removal efficiency of pump-and treat systems, Remedial Alternative 4 does not offer an increase in reduction of toxicity, mobility or volume when compared to Remedial Alternatives 2 and 3.

5. ***Short-Term Effectiveness***: The No Action alternative does not require short-term actions to be implemented at the site. In contrast, Remedial Alternatives 2, 3, and 4 include excavation of contaminated soil. Remedial Alternative 2 and 3 include capping of remaining soil. Soil removal and capping are proven technologies that can be implemented over a short period of time. Remedial Alternative 4, however, requires excavation of 100,000 cubic yards of contaminated soil. This alternative poses significantly more potential for short-term risks than Remedial Alternatives 2 and 3 which include excavation of about 10,000 cubic yards of soil.

6. ***Implementability***: No implementation is required for the No Action alternative. Remedial Alternative 4 is implementable; however, it is technically impracticable. Remedial Alternatives 2 and 3 are implementable. The asphalt cap in Remedial Alternative 2 requires a stormwater detention basin, which limits the implementability of future site development.

7. ***Cost***: The no action alternative has no direct cost. The total present worth for representative costs of Remedial Alternatives 2, 3, and 4 are $39,000,000, $25,000,000, and $101,000,000, respectively.

In summary, Remedial Alternative 1 is determined to be not sufficiently protective of human health and the environment. Remedial Alternative 4 is technically impracticable. The comparison of Remedial Alternatives 2 and 3 revealed that these alternatives provide equivalent protectiveness and compliance with ARARs. Alternative 2 and 3 are comparable in terms of long-term effectiveness, short-term effectiveness, and implementability. Alternative 3 provides more reduction of mobility through treatment with the phytoremediation cap. Alternative 3 is more cost effective than Alternative 2 and maximizes the future use of the land.

1.0 Introduction

This Feasibility Study (FS) report has been prepared for the WCP site in Waukegan, Illinois pursuant to Section IX of the September 27, 1990 Administrative Order on Consent between the United States Environmental Protection Agency (U.S. EPA) and North Shore Gas Company (NSG). The FS Report fulfills the requirements and scope for the FS Report contained in the Statement of Work for Conducting a Remedial Investigation and Feasibility Study at the WCP site. This report fulfills the requirements for development, screening, and evaluation of remedial alternatives and for preparation of an FS Report as outlined in Tasks VII, VIII, and IX of the October 1991 *Remedial Investigation/Feasibility Study (RI/FS) Final Work Plan* for the site (Barr, 1991a).

The scope of the FS Report as defined in the Work Plan has been to:

- Summarize the conceptual site model and identify and quantify affected media.
- Document remedial action objectives for affected media.
- Develop general response actions and identify, screen, and document remedial technologies for affected media.
- Assemble technologies into remedial alternatives, each of which addresses all affected media.
- Screen assembled alternatives on the basis of effectiveness, implementability, and cost.
- Provide a detailed analysis of retained alternatives against the first seven of a set of nine NCP evaluation criteria.
- Compare alternatives to each other using the same set of criteria.

The FS Report provides the basis for remedy selection by the U.S. EPA.

1.1 Project History

This FS represents a continuation of the Remedial Investigation process for the WCP Site. The main project phases prior to this FS Report consisted of the Remedial Investigation (RI), conceptual site model refinement, and treatability and technology testing. Work plans and reports submitted during these phases are listed in chronological order below. For those documents subject to U.S. EPA approval, the date of that approval is noted.

1.1.1 Remedial Investigation

RI field investigation activities were conducted in two phases; Phase I began on February 26, 1992 and Phase II began on August 16, 1993. These investigations were conducted in accordance with the following U.S. EPA approved documents:

- *Remedial Investigation/Feasibility Study, Final Work Plan*, October 24, 1991 (October 1991 WP)—U.S. EPA approval on November 15, 1991.

- *Final Sampling and Analysis Plan, Volume I: Field Sampling Plan*, October 24, 1991 (October, 1991 FSP)—U.S. EPA approval on November 15, 1991.

- *Final Sampling and Analysis Plan, Volume II: Quality Assurance Project*, October 24, 1991 (October, 1991 QAPP)—U.S. EPA approval on November 15, 1991. The QAPP was amended on January 14, 1994 and verbally approved by the U.S. EPA on January 26, 1994. The QAPP was also amended on June 5, 1998.

- *Project Health and Safety Plan*—U.S. EPA approval on November 15, 1991.

- *Remedial Investigation/Feasibility Study, Phase I Technical Memorandum*, July 1993 (July 1993 TM) This document included the Phase II Remedial Investigation work plan.—U.S. EPA approval on July 14, 1993.

Two reports of the remedial investigation results were required under the Consent Order: a Preliminary Site Characterization Summary (PSCS) and an RI Report. The purpose of the PSCS was to provide the U.S. EPA with a preliminary transmission of data collected during the RI and previous investigations before data evaluations were complete.

- *Preliminary Site Characterization Summary*, April 1994. U.S. EPA approval on May 5, 1994.

The RI Report contained site background and regional information; geotechnical and chemical data obtained from previous investigations conducted at or in the vicinity of the WCP site; a description of RI activities and methods for investigations of soil, groundwater, surface water, and surface features; an evaluation of site geology and hydrogeology; characterization of contaminant nature and extent; and evaluation of contaminant fate and transport (chemical characteristics and migration pathways) at the WCP site.

- *Remedial Investigation Report* (RI Report), February, 1995. U.S. EPA approval on February 16, 1996.

In 1995, using the information obtained during the RI and presented in the PSCS, a baseline risk assessment consisting of a Human Health Risk Assessment (HHRA) and a screening ecological risk assessment (ERA) for the WCP site was performed by CH2M Hill for the U.S. EPA (U.S. EPA, 1995a and 1995b).

- *Technical Memorandum, Waukegan Manufactured Gas and Coke Plant Site, Waukegan, Illinois. Human Health Risk Assessment* (1995).

- *Technical Memorandum, Waukegan Manufactured Gas and Coke Plant Site, Waukegan, Illinois. Ecological Risk Assessment* (1995).

1.1.2 Conceptual Site Model Refinement

Subsequent to the RI Report, supplemental sampling and data evaluation activities were performed to refine the conceptual site model (i.e., the description of the physical setting and natural processes at and near the site, the types of chemicals and their distribution in affected media, and the processes controlling the migration/attenuation of those chemicals). These supplemental activities consisted of groundwater and surface water sampling events in July 1996 and September 1997 and additional evaluation of the following: (1) site water balance, (2) interaction between groundwater and surface water at the beach east of the site, and (3) transport and attenuation of chemicals in groundwater. Supplemental sampling activities were conducted in accordance with letter work plans submitted to the U.S. EPA on June 28, 1996 and August 20, 1997 (Barr, 1996 and 1997b). The June 28, 1996 work plan was revised in accordance with U.S. EPA comments with the accepted version dated June 28, 1996. The August 20, 1997 work plan was verbally approved by U.S. EPA on September 5, 1997.

The results of the 1996 sampling and additional data evaluation were summarized in the April 1997 *Conceptual Site Model* report (Barr, 1997a) and submitted to the U.S. EPA for comment. Comments on the document were received from U.S. EPA in a letter dated June 16, 1997. The results of the 1997 sampling event were submitted to the U.S. EPA in a letter dated June 30, 1998 (Barr, 1998).

Following submittal of the Conceptual Site Model Report and discussion of various preliminary remedial alternatives evaluations with the U.S. EPA , draft remedial action objectives (RAOs) were submitted to the EPA. RAO development was described in the October 1997 submittal to U.S. EPA entitled *Draft Remedial Action Objectives and Development and Screening of Alternatives* (Barr, 1997c). U.S. EPA comments on the submittal were contained in a letter dated January 14, 1998.

1.1.3 Treatability and Technology Testing and Evaluation

Concurrent with conceptual site model refinement and risk assessment activities, several technology tests were conducted to evaluate potential remedial technologies with respect to soil and groundwater from the WCP site. Soil technology evaluations included thermal desorption, soil washing, fuel blending/cement kiln incineration, and phytoremediation. Groundwater technology evaluation testing included a slurry wall backfill mix design study, an electrochemical precipitation pilot study, and an aerobic bioremediation study.

Thermal Desorption

The thermal desorption technology evaluation testing was completed by Westinghouse Remediation Services, Inc. (Westinghouse). The testing was performed in accordance with the *Work Plan for Technology Evaluation Testing of Thermal Desorption for the Waukegan Manufactured Gas and Coke Plant Site*, which was submitted to U.S. EPA on November 5, 1993. The testing was conducted from December 1993 until January 1994. The results of the testing were submitted to U.S. EPA in the July 27, 1995 report entitled *Technology Evaluation Testing of Thermal Desorption for the Waukegan Manufactured Gas and Coke Plant Site*.

Soil Washing

The soil washing technology evaluation testing was completed by Westinghouse in accordance with the *Work Plan for Technology Evaluation Testing of Soil Washing Desorption for the Waukegan Manufactured Gas and Coke Plant Site*, 1993, submitted to U.S. EPA on November 29, 1993. The testing was conducted from March 1994 until April 1994. The results of the testing were submitted to U.S. EPA in the July 27, 1995 report entitled *Technology Evaluation Testing of Soil Washing for the Waukegan Manufactured Gas and Coke Plant Site*.

Fuel Blending/Cement Kiln Incineration

Five waste service vendors offering fuel blending/cement kiln incineration were contacted and asked to characterize tar-saturated soils from the WCP site relative to their acceptance criteria. In October 1993, five 1-gallon buckets of tar-saturated soil were shipped to the following vendors: Cadence Environmental Energy (Michigan City, Indiana), Heritage Remediation (Indianapolis, Indiana), 7-7, Inc. (Wooster, Ohio), Southdown Environmental (Crestview Hill, Kentucky) and Nortru, Inc.

(Detroit, Michigan). Except for Nortru, other service vendors provided analytical data, acceptance criteria, and cost estimates for the treatment of tar-saturated soils.

Slurry Wall Backfill Mix Design

Slurry wall backfill mix design testing was completed by IT Corporation. A work plan for the study, entitled *Slurry Wall Backfill Mix Design Work Plan*, was submitted to U.S. EPA in November 1994. Testing was conducted from March 1995 until October 1995. The results of the testing were submitted to U.S. EPA in the November 1995 report entitled *Slurry Wall Backfill Mix Design, Waukegan Manufactured Gas and Coke Plant Site, Waukegan, Illinois*.

Aerobic Bioremediation

Laboratory testing was performed by Fluor Daniel/Groundwater Technology, Inc. to evaluate the feasibility of aerobic bioremediation of the site groundwater. Various blends of groundwater from affected and non-impacted site groundwater were prepared for testing. The treatability testing protocols, results, and data interpretation were submitted to U.S. EPA in the May 1998 report *Treatability Study to Evaluate Aerobic Bioremediation of Contaminated Site Groundwater, Waukegan Manufactured Gas and Coke Plant Site* (Fluor Daniel/Groundwater Technology, Inc., 1998).

Phytoremediation

Evaluation of the potential applicability of phytoremediation to the WCP site soils was completed by Dr. John Fletcher of the University of Oklahoma. The evaluation summary was submitted to U.S. EPA on June 22, 1998 in a report entitled *Implementation of Phytoremediation at the Waukegan, Illinois, Gas and Coke Plant Site* (Fletcher, 1998).

The FS Report summarizes the results of each of these technology tests and incorporates the results into remedy screening and selection.

1.2 Report Organization

Section 1.0 of the FS Report describes the background and purpose of the report. Section 2.0 presents the conceptual site model including the physical setting and chemical distribution, migration, and attenuation in site soil and groundwater. RAOs for soil, groundwater, and surface water are developed in Section 3.0. Section 4.0 discusses the development and screening of remedial alternatives. The detailed analysis of the targeted alternatives is presented in Section 5.0. The comparative analysis is presented in Section 6.0.

2.0 Conceptual Site Model

2.1 Introduction

This section presents the conceptual site model for the WCP site. The discussion is based on information previously submitted in the February 1995 RI Report, as well as subsequent analyses performed on: 1) the site water balance; 2) the interaction between the beach and groundwater; and 3) the transport and attenuation of chemicals in groundwater. This section summarizes the results of these efforts, with detailed information provided in Appendices 2-A through 2-F.

The conceptual site model describes the physical setting and natural processes at and near the site, the types of chemicals and their distribution in affected media, and the processes controlling the migration/attenuation of those chemicals. This section focuses on the physical setting of the surficial sand aquifer at the WCP site and the natural processes occurring in and at the boundaries of this aquifer. The extensive data collection efforts completed at the site provide the basis for a detailed conceptual site model that is used to support remedy evaluation in subsequent chapters.

2.2 Physical Setting

The WCP Site is located in Waukegan, Illinois, on a peninsula between Waukegan Harbor to the west and Lake Michigan to the east, approximately 35 miles north of Chicago, as shown on Figure 2-1. Further information on the site geology, groundwater flow, and influences of Waukegan Harbor and Lake Michigan are discussed below.

2.2.1 Geology

Site geology is characterized by near-surface fill materials that were placed over a fine-grained sand unit. The sand overlies an 80-foot-thick till unit, which overlies a sequence of dolomitic bedrock formations. Figure 2-2 shows the surficial stratigraphy down to the till. (Figure 2-2 is a revision to cross section B-B' published as Figure 5.1-3 in the RI Report; the cross section was revised to show the sand unit thickness beneath the lake using information published in Shabica and Pranschke, 1993.) The characteristics of each unit above the bedrock are described below.

2.2.1.1 Fill

Fill deposits are present across the surface of the site at depths generally extending 2 to 12 feet below the ground surface. Demolition debris was placed at the WCP site at the time of demolition of the coke plant facilities in 1972 by Outboard Marine Corporation (OMC), and the debris was covered with a thin layer of soil. The entire site, including former pond areas, was filled and leveled as part of the demolition activities. The fill typically consists of reworked sand deposits with demolition and construction debris, as well as facility-related materials such as coal, coke, and slag.

2.2.1.2 Sand

The sand unit underlying the fill is generally 20 to 25 feet thick. It consists of a well-sorted fine to very fine sand containing 5 to 15 percent silt. Deeper portions of the sand unit typically show finer grain sizes than shallow portions. Measured porosity values range from 33 to 41 percent.

The longshore current in Lake Michigan causes a net transport of sediment from north to south along the western shore of the lake. Breakwaters extending out into the lake trap the sediment, causing sand to deposit and form a beach. This sediment transport is responsible for the formation of the sand unit on the Waukegan Harbor peninsula. The beach front moves lakeward as the sand, transported by longshore currents, accumulates. The sand accumulation is not a uniform or continuous process. Wind direction and wave action cause the beach to erode during some periods and grow during others. The beach growth over the years is described in Appendix 2-A. As discussed in Section 2.3, the growth of the beach is an important factor in explaining the distribution and attenuation of chemicals at the site.

The natural accumulation of beach sand was enhanced in the Waukegan Harbor area by construction of the north and south breakwaters between 1883 and 1885. These breakwaters intercepted the sand migrating with longshore currents, which led to the formation of the peninsula at Waukegan Harbor. From 1899 to 1904, the harbor was enlarged and deepened, and the excavated materials were likely used as fill for the peninsula. As shown on Figure 2-3 and in Appendix 2-A, the beach front, although receding at times, has generally been growing lakeward. The average rate of eastward growth of the beach near the site was 11 feet per year for the period from 1939 to 1988.

2.2.1.3 Till

The till underlying the sand unit is approximately 80 feet thick beneath the site. This unit consists of a hard lean clay with sand and some gravel. The surface of the till is overlain by a thin, discontinuous zone of silty gravel or gravel with sand, which, where present, has an average thickness of 0.3 feet. The surface of the till is irregular, and generally slopes gently downward from west to east beneath the peninsula.

2.2.2 Groundwater Flow

Groundwater flow at the site has been investigated through field measurements and mathematical models. The horizontal groundwater flow model developed during the RI was refined to account for differences in the distribution of infiltration on the peninsula, as described in Appendix 2-B. A supplemental conceptual model of vertical flow, described in Appendix 2-C, was developed to help understand the general nature of groundwater discharge to surface water. These models were used for evaluating and selecting an appropriate remedy. This section describes the general groundwater flow characteristics of the peninsula, describes the refinements made to the horizontal groundwater flow model, and explains the effect of beach accretion on groundwater flow over time.

Groundwater beneath the peninsula is driven by infiltration, which flows through the sand unit before discharging to the surrounding surface water. The sand unit is underlain by the virtually impermeable till layer. Groundwater in the sand unit occurs about 4 to 5 feet below the ground surface. The groundwater flow pattern consists of a hydraulic divide near the eastern boundary of the WCP site, with flow to the east and southeast (toward Lake Michigan) and flow to the west and southwest (toward Waukegan Harbor), as shown on Figure 2-4. Flow is mostly downward near the groundwater divide and mostly horizontal in other areas. Groundwater flow rates (average linear velocities) are very low near the groundwater divide, increasing to about 100 feet per year beneath the beach to the east, 60 feet per year at the harbor wall to the west, and 20 feet per year at the site boundary to the south. These velocities are calculated using the RI Report hydraulic conductivity estimate of 31 feet per day (1.1×10^{-2} cm/s) for the sand aquifer, coupled with measured and simulated horizontal groundwater gradients.

In a temperate climate such as that in Waukegan, the majority of the annual precipitation is returned to the atmosphere as evapotranspiration. The remainder of the water runs off or infiltrates. The infiltrating waters eventually discharge to the lake and harbor. The amount of infiltration at the WCP site was estimated during the RI to be 11 to 15 inches, or 33 to 45 percent of the annual 33-inch precipitation. However, dune areas around Lake Michigan are expected to have much higher infiltration. These areas are subject to lake spray and are composed of very permeable sand. Consequently, infiltration at the Waukegan dunes would likely be even greater than the 80 percent of annual precipitation reported for West Coast dunes (Frank, 1970). Higher infiltration at the beach is also a consequence of the sparse vegetation in the dunes area (resulting in decreased evapotranspiration), numerous depressions in which runoff accumulates, and high humidity and cool temperatures.

The horizontal groundwater flow model developed during the RI was refined to include higher infiltration at the beach, as discussed in Appendix 2-B. The beach infiltration that optimized the calibration of the refined model is approximately equal to the annual precipitation of 33 inches—a value consistent with the physical factors and literature information summarized above. The horizontal groundwater model was subsequently used to predict the average groundwater discharge to the harbor and the lake. The calculated groundwater discharge is 28 gpm to the harbor, 22 gpm to the lake (east of the site), and 16 gpm to the portion of the lake enclosed by the breakwater (i.e., the area east of OMC Plant No. 1 and the City Waterworks). Additional vertical modeling of groundwater discharge (described in Appendix 2-C) suggests that for that part of the sand aquifer which discharges to the lake, virtually all of the groundwater discharges within 250 feet of the shoreline.

As stated in Section 2.2.1, the shoreline of Lake Michigan moves in response to beach accretion and erosion. The shoreline also moves as a result of lake level changes. The zone of groundwater discharge to the lake necessarily changes in response to these movements. Figure 2-5 conceptually illustrates beach front positions with corresponding discharge zones for groundwater in the deeper portion of the sand aquifer for several time periods, during and after operation of the manufactured gas and coke plant. A more detailed evaluation of this effect is presented in Appendix 2-C. The horizontal orientation of the beach/groundwater interface produces upward movement of groundwater (and hence vertical mixing of the groundwater) prior to discharge to the Lake.

The stationary harbor boundary has produced a different groundwater discharge situation on the harbor side. At this side, groundwater discharges directly to the harbor through the sheetpile joints and any gaps that may exist in the wall. The location of groundwater discharge to the harbor has remained essentially unchanged over time, as shown on Figure 2-5. The vertically-oriented interface between the harbor and the groundwater produces an essentially lateral discharge of groundwater (and hence no vertical mixing in the groundwater).

2.2.3 Lake Michigan

The shore of Lake Michigan is currently 600 to 800 feet east of the WCP site. Groundwater flow patterns indicate that a portion of the groundwater from the site discharges to the lake. Information about the groundwater discharge zone to the lake was combined with an evaluation of wave action and currents in the lake to more clearly evaluate this groundwater/surface water interaction, as presented in Appendix 2-D.

Lake Michigan supports commercial and sport fishery and is the source of drinking water in the Waukegan area. The water surface elevation of the lake varies over both short- and long-term periods. The water levels typically vary about 1 foot in any one year; levels are generally highest during the summer months and lowest during the winter months. Annual average water levels have varied over a range of about 6 feet since 1918 (Appendix 2-A). Factors influencing long-term changes in lake level include precipitation, evaporation (influenced by temperature, wind, relative humidity and solar radiation), natural changes in outlet channels and management of outlet flow rates, surface water inflow, and snowmelt from the surrounding watershed. Short-term lake level fluctuations, which tend to be highly variable in location and time, are strongly influenced by barometric pressure, winds, and seiches.

As stated in Section 2.2.1, wave action and longshore currents are important mechanisms along the shore of Lake Michigan. These mechanisms, which move and deposit sediments in the vicinity of the shoreline, also affect groundwater discharges to lake water. Surface water movements affecting discharged groundwater are divided into two zones: the near-shore zone; and the longshore current (or littoral drift) zone. Depending on wind direction, the near-shore zone consists of either a breaker zone or a wind-induced current zone. The breaker zone is a well-mixed area close to the shore, defined as the area where the waves break. Based on a review of aerial photographs of the general vicinity of the site, the breaker zone extends 300 feet or more out from the lakeshore, encompassing the groundwater discharge zone. Winds from the north, east, and south cause breakers, producing a breaker zone. On-shore winds (the prevailing westerlies) do not create breakers, but cause wind-induced currents that mix and transport the water. Considering wave- and wind-driven currents, the normal dilution of groundwater discharges in this zone is estimated to be 12,000 to 1, as discussed in Appendix 2-D. The dilution could easily range in excess of 20,000 to 1 during the times when breaker waves are more than 2 feet high. Calm conditions, during which dilution may be as low as 2,900 to 1, occur at a low frequency. According to measured wind velocities at a lake-side Waukegan weather station, calm conditions occurred only 1.4 percent of the time for the period from 1951 through 1964.

A similar analysis was performed for the near-shore zone in the breakwater area (between the north harbor wall and the north breakwater), as explained in Appendix 2-D. The normal dilution of groundwater discharges in this zone is estimated to be 7,600 to 1. Dilutions could easily exceed 20,000 to 1 in this zone in windy conditions. Calm conditions may produce dilutions as low as 1,600 to 1.

The water in the near-shore zone eventually mixes into longshore currents. The longshore current zone extends more than 3,000 feet into the lake, as evidenced by sediment transport visible on aerial photographs. Continuous velocity measurements of longshore currents were made over a period of 95 days during a study performed by Argonne National Laboratories (ANL) in 1979 (Harrison, 1979). The reported velocities had an average daily current velocity of 0.082 meters per second (m/s), or 0.27 feet per second (ft/s), corresponding to a mixing ratio of lake water to groundwater of about 50,000 to 1. The actual attenuation rates are expected to be even greater than these mixing ratios since the ratios do not account for the biological, chemical, and physical attenuation mechanisms explained in Section 2.3.2. The results presented in Appendix 2-D do not account for these attenuation mechanisms and therefore should be viewed as highly conservative.

2.2.4 Waukegan Harbor

Waukegan Harbor is an industrial and commercial harbor used by lake-going freighters. It is also used by private boats to reach the repair, supply, and docking facilities at Slip No. 4. A public marina is located in the southwest corner of the harbor. OMC conducts performance testing of outboard motors in the harbor and uses the harbor as a lake access point for boats operated during motor testing.

The harbor is dredged periodically in order to maintain access to the harbor for freighters, barges, and private boats. Both dredging and passage of boats cause sediments in the harbor to be routinely disturbed. Such disturbances mix sediments into the water column, disrupting the benthic zone and influencing harbor water quality.

The harbor water and sediment quality is also impacted by overland flow, storm sewers, and permitted discharges. Land use in the watershed draining to the harbor is primarily commercial and industrial with significant areas of railroad and highway right-of-way and lesser areas of open and urban residential areas. Both municipal and private storm sewers discharge to the harbor. Part of the downtown area of Waukegan drains to the harbor by storm sewer. Discharges from industrial activities to Waukegan Harbor include non-contact cooling water and other permitted discharges under the National Pollutant Discharge Elimination System (NPDES) program. In the early 1980s, oil from releases at the railroad tracks located west of the harbor washed through the Madison Street sewer system into Waukegan Harbor (Bleck, 1993).

A former storm sewer, which discharged water from OMC Plant No. 2 to former Slip No. 3, is believed to have been the primary source of polychlorinated biphenyl (PCB)/oil mixtures found in the harbor sediments (U.S. EPA, 1981). Subsequently, in 1991, portions of the inner harbor were dredged to remove sediments containing PCBs as part of the Waukegan Harbor Superfund Site remedy. The dredged sediments were treated and placed in former Slip No. 3.

Lake Michigan influences Waukegan Harbor in several ways. Most significantly, the nearly continual exchange of water between the lake and harbor prevents stagnation of the harbor water. A study performed by ANL in 1979 (Harrison, 1979) found that average wind-induced currents in and out of the harbor are sufficient to exchange the volume of water in the harbor in one to eight days (with an average exchange period of about four days for the study). The ANL study concluded that there is a reciprocal exchange of water between the lake and harbor, with flow at the harbor surface moving in one direction and flow at depth moving in the other. The lake also causes mixing in the harbor by direct waves entering the harbor through the entrance channel.

Based on the lake/harbor water exchange and groundwater discharge rates to the harbor, harbor waters provide net flows to mix with site groundwater at ratios of 6,000 to 1 to 800 to 1. The average mixing ratio is approximately 1,600 to 1. Groundwater flow to the harbor is a gradual phenomenon dispersed over a large area. Attenuation mechanisms (biological, physical, and chemical) which also reduce chemical concentrations are not considered in the mixing model. Consequently, the 1,600 to 1 ratio is a conservative estimate of the potential effect of site groundwater on harbor water quality.

2.3 Chemical Distribution, Migration, and Attenuation

This section describes the distribution of chemicals in site soil, groundwater, and surface water/sediment in the vicinity of the site, including presentation of post-RI surface water and groundwater data. The chemical distributions are evaluated within the context of the changing groundwater flow conditions on the lake side and the relatively stable groundwater flow conditions on the harbor side.

2.3.1 Soil

The zone above the water table at the site (i.e., the vadose zone) is from 0 to 4.5 feet below ground level. The nature and extent of chemicals in the vadose zone and their potential for migration to air and groundwater are discussed below.

2.3.1.1 Chemical Distribution

The major chemicals of concern in vadose zone soils at the site are polynuclear aromatic hydrocarbons (PAHs) and arsenic, as explained in Section 3. The distribution of PAHs and arsenic in vadose zone soils is shown on Figures 2-6 and 2-7.

Figure 2-8 shows the mass of PAHs in the vadose zone at the site as a function of soil volume. This figure is based on the concentration contours shown on Figure 2-6, supplemented by observations made during the remedial investigation and documented in the RI report. The figure shows that about 85 percent of the mass of PAHs at the site is present in about 7,000 cubic yards of soil.

High arsenic concentrations are largely restricted to one area on the eastern part of the site (Figure 2-7). The mass of arsenic in the vadose zone is shown on Figure 2-9 as a function of soil volume. The quantities are based on Figure 2-7, supplemented by observations made during the remedial investigation and documented in the RI report. The percent mass values shown on the figure include all vadose zone arsenic above 16 milligrams per kilogram (mg/kg), the 95 percent Upper Confidence Limit (UCL) on the mean for the background soil sample concentrations (excluding sample BS-03, an apparently high outlier).

There are two soil stockpiles at the WCP site. The Designated Soil Stockpile is the fenced cell immediately south of Slip No. 4. The soil in this cell was identified by testing and by visual selection during construction of Slip No. 4 in an area affected by the former wood-treating operation. Testing of three samples from the Designated Soil Stockpile during the RI found PAH concentrations of 194, 222, 207 and 205 mg/kg, and cPAH concentrations of 35, 34, 87 and 83 mg/kg (Samples DS01, DS02, DS03, and DS03 Duplicate, respectively). No benzene was detected, and reported arsenic concentrations were less than 13 mg/kg.

The other soil stockpile, located along the west side of the site, is dredge spoils from construction of Slip No. 4 and from dredging of the channel leading into Waukegan Harbor (called the Outer Harbor). Soil borings 30 and 31 were placed in this soil during the RI. Samples SB3003, SB3007, SB3103, and SB3107 were reported to have the following concentrations: PAHs: 142, not detected, 2.8, and 5.5 mg/kg; cPAHs: 83, not detected, 1.1, and 2.2 mg/kg; arsenic: 9.8, 3.5, 6.0, and 1.6 mg/kg. PCBs were reported at 2.0, 0.14, not detected, and 0.81 mg/kg, respectively. No benzene or other site-related volatile organic compounds were detected in these samples.

2.3.1.2 Chemical Migration and Attenuation

Chemicals present in soils above the water table may be transported to the atmosphere (via volatilization or airborne particulates) and to the groundwater (by infiltration).

Chemical migration from vadose zone soils to air does not pose unacceptable risks at the WCP site. This is due to two factors. First, the analytical results for the surface soil samples (from the top 6 inches of soil at the site) indicate that volatile and semivolatile chemicals are not present. Second, health and safety monitoring during intrusive RI trenching activities did not indicate unacceptable exposures.

Migration of chemicals from the vadose zone soils appears to influence limited areas of the shallow portion of the sand aquifer. Higher concentrations of PAHs and arsenic in the shallow portion of the sand aquifer are spatially associated with the higher concentrations of these parameters in vadose zone soils. The observed distribution of low molecular weight PAHs (the more soluble and mobile PAHs) and arsenic indicates that vadose zone soils act as a relatively limited source of these parameters to groundwater in the shallow portion of the sand aquifer. While vadose zone soils may be a source for some chemical migration, the spatial extent and concentrations of low-molecular-weight PAHs in the shallow portion of the sand aquifer on the eastern and southern portions of the site are less than might be expected in comparison to PAH concentrations in the vadose zone soil in these areas. Lower-than-expected concentrations may be due to natural attenuation mechanisms, such as aerobic bioremediation. Such natural attenuation mechanisms may also account for the observed absence of significant levels of benzene and phenols in the shallow portion of the sand aquifer.

The highest chemical concentrations in groundwater occur in the deeper portion of the sand aquifer. Site data indicate that these concentrations are not due to current, continuing downward migration of chemicals in the vadose zone via infiltrating precipitation. This observation is supported by a number of facts:

1. As shown in Table 2-1, the concentration of both inorganic (arsenic and cyanide) and organic (phenol and benzene) chemicals in the deep groundwater are orders of magnitude greater than those in the shallow groundwater.

2. Phenol is generally not detected in vadose zone soils or in the shallow groundwater, although it is present at relatively high concentrations in the deeper groundwater. Phenol is also detected in saturated soils of the deep portion of the sand aquifer where soil and groundwater concentrations of phenol appear to be in equilibrium with each other. This suggests that soil concentrations in the deep portion of the aquifer are the result of adsorption of phenol from groundwater.

3. Soil and saturated zone concentrations of benzene, arsenic, and cyanide decrease significantly with depth. In contrast, groundwater concentrations for these parameters increase by orders of magnitude with depth.

2.3.2 Groundwater

The generalized vertical distribution of chemicals (Table 2-1) clearly demonstrates a stratification in chemical concentrations between groundwater in the shallow and deep portions of the aquifer. These results were further confirmed by the groundwater sample data collected in 1996 and 1997. The observed stratification appears to be due to past aqueous discharges, as opposed to dense nonaqueous-phase liquids.

2.3.2.1 Chemical Distribution

The groundwater quality data published in the RI Report have been supplemented with sampling conducted in July/August 1996 and September 1997. These included multi-depth HydroPunch groundwater samples along a transect on the beach between MW-13 and the lake shore (i.e., along a line parallel to groundwater flow in this area). The locations of sampled wells and the four transect borings are shown in Figure 2-10. Figure 2-11 is a portion of the cross section from Figure 2-2 showing sampling depths along the beach transect. The monitoring well sample laboratory and field data are listed in Table 2-2. The HydroPunch sample laboratory and field data are listed in Table 2-3. Soil samples were also collected for organic carbon content analysis. The results of those analyses are in Table 2-4. The boring logs for the HydroPunch sampling are in Appendix 2-E. Field sampling logs and corresponding data validation documentation for the 1996 and 1997 samples have been submitted to the EPA under a separate cover letter dated June 30, 1998.

The 1997 beach transect data are presented in cross sections on Figures 2-12 through 2-17 for chloride, ammonia, arsenic, phenol, phenols (total), and thiocyanate, respectively. These figures show the strong vertical stratification of concentrations. The concentrations are at approximately background levels from the top of the water column down to depths within about 10 feet of the base of the sand unit. The concentrations typically jump by order-of-magnitude steps until they reach their maximum in the lower few feet of the sand unit.

Figures 2-18 through 2-22 present plan views of groundwater and surface water data from the site investigation. The concentration isopleths on the figures are based on the 1996 and 1997 deep well and deep HydroPunch data and, as such, represent the highest measured values from the shallow/deep groundwater quality data sets.

As shown on Figures 2-12 through 2-22, samples of groundwater from the shallow portion of the sand aquifer beneath the site (i.e., the upper 20 to 25 feet of a 25- to 30-foot-thick saturated zone) show arsenic concentrations generally in the range of 0.01 to 0.3 milligrams per liter (mg/L), ammonia concentrations in the range of 1 to 10 mg/L, and sporadic detections of phenol and benzene. Shallow groundwater was determined to exhibit borderline aerobic/anaerobic conditions.

In contrast, groundwater in the deep portion of the sand aquifer (i.e., the lower 5 feet of the 25- to 30-foot saturated zone), shows: anaerobic conditions; arsenic concentrations of 10 to 60 mg/L; ammonia concentrations of 100 to 2,500 mg/L; phenol concentrations of 100 to 1,000 mg/L; benzene concentrations of approximately 1 mg/L; and isolated detections of PAH compounds. It is noteworthy that for phenol the transition zone from background (shallow) to maximum (deep) concentrations is very thin compared to that for chloride (Figures 2-15, 2-16, and 2-12). Anaerobic biodegradation processes operating on the more dilute concentrations may be responsible for this thin transition zone, as discussed in Section 2.3.2.4.

2.3.2.2 Chemical Migration and Attenuation

As discussed in Section 2.3.1.2, the vadose zone soil is not the current source of chemicals in the deep portion of the sand aquifer. The RI considered the potential presence of dense non-aqueous-phase liquid (DNAPL) and dense aqueous solutions (i.e., solutions with a specific gravity greater than one) as possible sources for the deep groundwater chemicals. As discussed below, DNAPL and dense aqueous solutions are not sources of the deep groundwater contamination at the site. Rather, the observed groundwater quality stratification is attributable to the site hydraulic characteristics and the chemical mixture (constituents and concentrations) of aqueous discharges during plant operations or during plant demolition. These findings are supported by recent modeling efforts and by the RI results, as described below.

Relevant site hydraulic characteristics have been assessed using the groundwater model described in Appendix 2-B. This model was used to explore the likely effects of groundwater flow on contaminant distribution in the groundwater, as discussed in Appendix 2-C. Prior to demolition of the plant and closure of the site, the site groundwater chemical characteristics were likely dominated by aqueous discharges near the groundwater divide. The model indicates that water infiltrating from aqueous discharges located near the groundwater divide would affect the entire aquifer (vertically down to the base of the aquifer) and migrate laterally throughout nearly the entire thickness of the aquifer. Since the elimination of these discharges after plant demolition in 1972, infiltration has been the dominant factor influencing groundwater flow and chemical distribution. The effects of this infiltration have been more significant for the shallow portion (upper 20 to 25 feet) of the sand aquifer, contributing to the current stratification of very low concentrations in the shallow portion of the sand aquifer and much higher chemical concentrations in the deep portion (the lower 5 feet) of the sand aquifer. The infiltration has had both a flushing effect and a role in encouraging aerobic biodegradation, which is discussed in Section 2.3.2.3 and Appendix G. Thus, natural flushing processes, the site's hydraulic characteristics (as demonstrated by site groundwater models), and aerobic biological degradation in the shallow portion of the sand aquifer account for the observed groundwater quality stratification.

To assess the potential presence of DNAPLs during RI investigations, most of the 78 soil borings placed at the site and beach during the RI extended to the top of the till unit, and analytical samples were collected from the interval above the till. Field screening observations and analytical results of soil and groundwater samples identified no pools of DNAPL at the site. A small amount of separate-phase oily material was observed to be present between grains of gravel from one soil interval above the till unit in one boring (SB-41); however, no sheen or DNAPL was observed to be present in the water in the borehole. Furthermore, the chemistry of impacted soils in the vadose zone, from which DNAPL would have migrated, cannot explain the chemistry of the deep groundwater. Thus, site data indicate that there is no migration of DNAPL at or from the site (refer to Section 7.9 of the RI Report for more information relating to this conclusion).

Potential migration of dense aqueous solutions from the site was also investigated during and following the RI. Specific gravity tests of site groundwater were performed for the specific purpose of identifying density differences between groundwater in the shallow and deep portions of the sand aquifer. These data show a small difference between specific gravities for groundwater samples from the shallow portion of the sand aquifer and samples from the deep portion of the sand aquifer.

However, evaluations of the density difference show it to be too small to produce a difference in the flow regimes of the shallow and deep portions of the sand aquifer.

To identify a potential source of the contaminants found in the deep portion of the sand aquifer, characteristics of the groundwater chemical mixture and measured constituent concentrations were assessed. The observed chemical mixture in the deep portion of the sand aquifer is similar to the chemical composition of various aqueous effluents from coal conversion (i.e., coking/manufactured gas) operations, both in major constituents and in the general order of magnitude of concentrations. Tables 2-5 and 2-6 list chemical characteristics of typical coal conversation plant effluents (these are literature values—no data from site aqueous discharges were found). The similarity between these literature values and site groundwater data from the deep portion of the sand aquifer suggests that historic site operations or demolition activities, which involved aqueous discharges, were the contributing source of chemicals in the deep portion of the sand aquifer.

The results of the RI and post-RI modeling, sampling, and evaluations lead to the conclusion that the water quality of the deep portion of the sand aquifer is not attributable to DNAPL or dense aqueous solutions. The groundwater quality stratification is consistent with aqueous discharges during plant operations or demolition, and the nature of groundwater flow after plant demolition.

2.3.2.3 Attenuation Mechanisms

The groundwater flowing east from the groundwater divide toward and beneath Lake Michigan may be subject to attenuation mechanisms including dilution, anaerobic degradation processes, and aerobic degradation processes. These natural attenuation processes occur throughout the sand aquifer, but are inhibited in the bottom five feet, where concentrations are high and flushing is limited. The 1997 groundwater quality data for the beach transect (Figures 2-10 through 2-17) provide a basis for a more complete assessment of the potential for degradation mechanisms to reduce groundwater constituent concentrations prior to discharge to Lake Michigan. Appendix 2-F describes the recent evaluation of anaerobic processes on groundwater contaminant fate and Appendix 2-G describes recent evaluations of aerobic degradation processes; these evaluations support the following conclusions:

Anaerobic Processes (Appendix 2-F)

- An anaerobic biologically-active zone exists at the upper fringe of the deep portion of the sand aquifer, in the zone of Constituent of Concern (COC) concentration transition.

- Anaerobic degradation processes act to reduce phenol concentrations in the fringe zone described above. Modeling suggests that anaerobic degradation reduces the mass flux of phenol by about 20 percent for flow toward the lake shore, with possible reductions of as much as 40 percent.

- Anaerobic degradation processes may also be significant at the leading edge and lateral fringes of a phenol plume resulting in attenuation and slowed migration of the plume.

Aerobic Processes (Appendix 2-G)

- Aerobic biological treatment can successfully treat the groundwater of the deep portion of the sand aquifer, which resembles coal conversion wastewater. Aerobic biological treatment processes are extensively, routinely, and successfully used to treat coal conversion wastewaters in industrial settings.

- Aerobic degradation of phenols, thiocyanate, and ammonia in site groundwater has been demonstrated after dilution of the groundwater, and phenol- and thiocyanate-degrading aerobic microorganisms are present in site soils. This was demonstrated by the aerobic treatability study using site groundwater. The study also showed that undiluted groundwater inhibited biological activity.

- Aerobic biological activity will be promoted by oxygen from the atmosphere and the dissolved oxygen from infiltration and penetration of Lake Michigan water, which are the primary sources of oxygen for aerobic biological activity at the site.

- Significant aerobic degradation of residual organic compounds has taken place after demolition and closure of the site in the shallow portion of the sand aquifer. This conclusion is supported by the lack of detectable or significant concentrations in the shallow portion of the sand aquifer in the former aqueous discharge areas at the groundwater divide or the dunes area east of the site.

The above conclusions (Appendices 2-F and 2-G) indicate that naturally-occurring degradation processes can act to significantly reduce concentrations in fringe zones at the vertical or lateral edges of the groundwater plume. These results also suggest that such degradation processes can reduce residual constituent concentrations that might remain following periods of active groundwater and soil remediation.

2.3.3 Surface Water and Sediment

Currents in both the lake and the harbor continuously displace and mix the surface water. Turbulent surface water mixing is orders of magnitude more vigorous than laminar groundwater mixing. As impacted groundwater discharges to surface water, these natural mixing processes significantly reduce its impacts on the lake and the harbor. In addition, other attenuation mechanisms, such as biodegradation, chemical changes, and sedimentation, tend to further reduce chemical concentrations. This section describes the results of water quality sampling in the lake and the harbor and discusses the attenuation of chemicals once they have been discharged to surface water.

2.3.3.1 Surface Water and Sediment Quality

The 1993, 1996 and 1997 surface water sampling locations and data for ammonia, phenol, benzene, and arsenic in the site vicinity are shown on Figures 2-18 through 2-22, respectively. The 1996 and 1997 data are listed in Tables 2-7 and 2-8, respectively. Figure 2-23 shows the 1997 surface water sampling locations. The field sampling logs and data for the 1993 sampling event are in the RI report.

As noted in the RI, the 1990 Illinois Environmental Protection Agency (IEPA) and the 1993 RI surface water samples showed no exceedance of the Illinois Lake Michigan Water Quality Standards (standards) for chemicals from the site. In addition, routine annual water sampling conducted by the city of Waukegan Waterworks also showed no exceedances of standards. (These results were published in Appendix 3-E to the RI report.)

In 1996, the lake samples were collected about 100 feet offshore in the groundwater discharge zone and the harbor sample was collected at the harbor entrance. For the July 1996 harbor and lake samples, total phenolic compound concentrations were measured (consistent with surface water phenolic standards) using the 4-aminoantipyrine colorimetric (4AAP) method. This method does not identify individual phenolic compounds but produces a single result representing the minimum concentration of total phenolic compounds. The July 1996 samples exceeded the phenol standard for the lake. This exceedance was attributed to the runoff from an earlier heavy rain. For confirmatory purposes, the lake and the harbor were re-sampled in August 1996. The analysis for phenolic compounds was performed using both the 4AAP method and the gas chromatograph/mass spectrometer (GC/MS) method. GC/MS is a more exact analytical method which identifies and quantifies concentrations of specific individual phenolic compounds. The August 1996 samples had no exceedances of the 4AAP standard for phenolic compounds (0.001 mg/L for the open waters of

Lake Michigan, 0.1 mg/L for harbors and breakwater areas) and no exceedances of the GC/MS analytical method detection limits for individual phenolic compounds (0.006 mg/L).

The September 1997 surface water sampling included samples at 15 locations within an area extending from more than a mile south of the site to a location 2 miles north of the site. As in 1996, no phenolic compounds were detected using the compound-specific GC/MS analytical method. The 4AAP method analysis reported concentrations of phenols as high as 0.5 mg/L (sample LM-6N in Table 2-8). No individual phenolic compounds were detected at the detection limit of 0.002 mg/L. The samples with the highest 4AAP method concentrations were found opposite the Illinois State Beach Park (LM-6N), the North Shore Sanitary District Sewage Treatment Plant (LM-4N), and the southernmost sample (LM-2S), which was collected more than a mile south of the site. These results further confirmed that the anomalous July 1996 4AAP exceedance near the site was likely not site-related.

The ammonia concentrations in the July 1996 surface water samples in the harbor and the lake were between 0.076 and 0.097 mg/L. In August, the surface water was resampled, and the ammonia concentrations were overall similar to those from July. The ammonia concentration in the harbor sample was 0.086 mg/L and the ammonia concentration in a composite of the three lake samples and the harbor sample was 0.094 mg/L. The limited 1996 sampling did not include sample collection from background near-shore zone areas, so no basis is available for assessing the source or the extent of the observed ammonia concentrations. The 1996 results exceeded Lake Michigan open water standards for ammonia (0.02 mg/L), but not harbor and breakwater area standards (15 mg/L). No ammonia was reported in the 1997 surface water samples at a detection limit of 0.02 mg/L. The 1997 samples all met the stringent open water standards.

2.3.3.2 Chemical Attenuation

As groundwater discharges to the lake and the harbor, natural mixing processes induced by wave action and currents further reduce the impacts of these discharges on surface water quality. Estimated surface water concentrations of site chemicals for the peak annual mass fluxes from groundwater (i.e., the maximum value for any time into the future) as described in Appendix 2-D, are summarized in Table 2-9. The reported values ignore other attenuation mechanisms (such as biological and chemical degradation), as well as sedimentation effects, and, as a result, are conservative.

The surface water quality calculations indicate that the groundwater mass flux is not expected to produce exceedances of standards in the breakwater area or in Waukegan Harbor. The HHRA (U.S. EPA, 1995a) evaluated ammonia and phenol in the surface water; these compounds are not considered to pose a human health risk, but at high enough concentrations, they can be detrimental to aquatic life (U.S. EPA, 1995b). National Ambient Water Quality Criteria for the protection of aquatic life are included in Table 2-9. Based on the mass loading evaluation, no exceedances of these criteria are expected for any of the surface waters under any of the mixing scenarios. No exceedances of the very stringent water quality standards for the open waters of Lake Michigan are calculated for the longshore current zone, except for phenols under the lowest mixing scenario. Phenols are readily degradable, a fact not incorporated in the modeling, which will act to reduce the estimated concentration. The only exceedences of the stringent open water standards calculated for the nearshore zone east of the site are phenols and ammonia. None of the calculated concentrations exceeded aquatic life protection criteria. Cyanide and arsenic fluxes in the groundwater from the site are several orders of magnitude below the fluxes that might be expected to cause exceedance of standards in the lake or the harbor.

2.3.4 Chemical Distribution, Migration, and Attenuation Summary

For media of concern in and around the WCP site—soil, groundwater, surface water/sediment—the distribution and migration of site chemicals is summarized as follows:

Soil—PAHs and arsenic are the major COC in vadose zone soils. Approximately 85 percent of the mass of PAH impact at the site is present in tarry soils on the eastern portion of the site and the oiliest soils just south of Slip No. 4. High concentrations of arsenic are largely restricted to the eastern part of the site. The migration pathway from vadose zone soil to air does not pose an unacceptable risk. The pathway from soil to groundwater via infiltration is not a current source of contamination found in the deep groundwater.

Groundwater—There is evident stratification in chemical concentrations between groundwater in the shallow and deep portions of the aquifer at the site. The concentrations of phenol, ammonia, benzene, arsenic, cyanide, and thiocyanate in groundwater of the deep portion of the aquifer are orders of magnitude higher than those in the shallow portion. Past aqueous discharges during plant operations or plant demolition appear to be the source of observed chemical constituents in the deep portion of the sand aquifer. In the period since demolition of the plant, the residual plume in the shallow portion of the sand aquifer has been flushed by infiltration-driven flows. Attenuation processes have reduced concentrations and the mass flux of organic compounds such as phenol through aerobic and anaerobic biodegradation along the vertical and lateral fringes of the plume.

Surface Water/Sediment— Natural mixing processes, induced by wave action and currents, have attenuated the impacts of groundwater discharges to both the lake and the harbor. Sampling of Lake Michigan during 1990 and 1993 did not show any exceedance of standards for site chemicals. The 1996 sampling indicated that ammonia may exceed the Lake Michigan open water standard in the near-shore zone, but the 1997 sampling and surface water current measurements suggest that the 1996 data may not reflect site-related impacts. The surface water quality calculations also indicate that the peak groundwater mass flux is not expected to produce exceedences of standards in the harbor or breakwater area, and is not expected to exceed aquatic life protection criteria in the lake or harbor.

3.0 Remedial Action Objectives

3.1 Overview

This section presents the RAOs for the WCP site. RAOs have been developed for soil and for groundwater. RAOs provide a basis for evaluating potential remedial action alternatives. Development of site-specific RAOs took into consideration Applicable or Relevant and Appropriate Requirements (ARARs), the HHRA, the ERA, and the site conceptual model.

3.2 RAOs for Soil

Development of RAOs for soil includes consideration of potential future risks which may be associated with the soils of the site. The NCP requires that a range of risks (10^{-4} to 10^{-6} excess cancer risk) be evaluated. Lower allowable risks (10^{-6}) would be protective of potentially greater exposures; for example, a future residential exposure scenario. Higher allowable risks (10^{-5} or 10^{-4}) would be considered where the exposed population is small, or where it is unlikely children and sensitive populations would be exposed; for example, a future commercial/industrial exposure scenario. For developing these RAOs, an allowable risk of 10^{-6} has been used as a point of departure.

Future land use has been considered for the WCP site in Appendix 3-A. The WCP site is located within a commercial/industrial area, and will most likely continue to be nonresidential. As such, higher potential future risk may be appropriate in the development of RAOs for soil.

Development of RAOs for soil was based on the conclusions of the HHRA and ERA, supplementary human health risk evaluations, and a review of ARARs, as summarized below. This information was used to develop site-specific target soil concentrations (TSCs) as further discussed in Appendices 3-B and 3-C. The TSCs have been computed for a hypothetical future residential use as well as the more probable non-residential future land use.

The RAOs for soil are to:

- Protect human health by reducing or eliminating exposure (direct contact, ingestion, inhalation) to soil with concentrations of contaminants representing an excess cancer risk of greater than $1x10^{-6}$ as a point of departure and a hazard index (HI) greater than 1 for reasonably anticipated future land use scenarios.

- Protect the environment by minimizing/eliminating the migration of contaminants in the soil to groundwater or to surrounding surface water bodies.

3.2.1 Review of HHRA for Soil

An HHRA was performed by CH_2M Hill for the U.S. EPA at the WCP Site (U.S. EPA, 1995a). The HHRA evaluated human health risks under "current" and hypothetical future occupational (commercial or industrial), and hypothetical residential site use scenarios. The HHRA considered very conservative exposure assumptions as RME (reasonable maximum exposure), as well as somewhat less conservative assumptions as CTE (central tendency exposure). With the exception of the exposure parameters relating to time (frequency, duration, length of time) and dilution factors, EPA default values were generally used in the HHRA evaluation. Professional judgment was used to estimate many of the time-related parameters.

Both the RME and CTE exposure assumptions produce values which would be considered preliminary remediation goals (PRGs). In accordance with EPA guidance, PRGs are intended as conservative screening values to be used in preliminary decisions regarding the need for and extent of investigative efforts or remedial measures. As such, the RME and CTE values were calculated using conservative assumptions.

Inherent in any risk evaluation is an "exposure domain." The exposure domain is the land area associated with the exposure scenario. In the development of the HHRA, EPA lumped data into sets which represent physical areas of the site. For example, exposure to future boat yard workers was assessed over a defined area of approximately 5 to 7 acres which included the boat storage yard as well as area around the Larsen Marine office facility. Similarly, the area of elevated contamination was an area of 6 acres which included the highest observed PAH and arsenic concentrations at the site.

For future scenarios, an exposure domain should be representative of the likely area where the exposure will occur. For instance, a construction crew placing utility pipes (storm sewer, sanitary sewer, and water) might take 60 days to lay 4,500 feet of pipe. During that work, they will have trenched through approximately 2 acres of land (assuming a 20-foot-wide trench). Therefore, the exposure domain for the utility worker scenario presented in Appendix 3-B is 2 acres. The average soil contamination conditions in a 2-acre area would be used to determine the carcinogenic risk. The construction worker would have a similar exposure domain to a utility worker, likely on the order of 2 to 5 acres. Finally, for a future industrial worker, the exposure domain would correspond to the industrial property, which exceeds 10 acres for each of OMC Plants No. 1 and No. 2. For a property such as the WCP site, an exposure domain of 5 acres represents a conservatively small domain, and is adopted for commercial/industrial risk evaluations in this FS.

3.2.1.1 Target Soil Concentrations

When evaluating the site-specific remediation goals, as in this feasibility study, the PRGs calculated using RME and CTE exposure scenarios may be overly conservative. Therefore, to determine cleanup action levels, target soil concentrations (TSCs) based on site-specific conditions were calculated. The exposure scenario used to develop the TSCs is considered a representative high exposure (RHE). The development of the RHE exposure scenario is presented in Appendix 3-B.

For the development of TSCs, COCs were selected from the RME risk calculations in the HHRA by reviewing the non-residential exposure scenarios (occupational, trespassers, and utility worker scenarios). Constituents in these HHRA scenarios were retained as COCs if they contributed at least a 10^{-6} excess cancer risk or if they had a noncarcinogenic HI of 0.1 or more. The COCs identified were carcinogenic PAHs (cPAHs), arsenic, PCBs, benzene, naphthalene, dibenzofuran, and 4-methylphenol. These COCs accounted for more than 90 percent of the carcinogenic risk and more than 80 percent of the noncarcinogenic risk in the future non-residential scenarios in the HHRA. The arsenic TSC accounts for both acute and chronic effects.

3.2.2 Review of ERA for Soil

A screening ERA was prepared in November 1995 for the U.S. EPA by CH_2M Hill for the WCP site (U.S. EPA, 1995b). The primary purpose of the screening ERA was to evaluate the potential for contaminants in surface soil, surface water, and groundwater to have an adverse impact on specific terrestrial and aquatic environments within or near the site. If the potential for such impacts had been identified, then a detailed site-specific ERA would have been conducted. The risks identified in the screening-level ERA did not warrant a detailed ecological risk assessment.

The ERA evaluated terrestrial life exposure to surface soil contaminants. The ERA assessed risk to organisms directly exposed to contaminated media. Organisms exposed via indirect pathways, such as ingestion of contaminated food sources, were considered less likely to be at risk since the soil contaminants evaluated are not highly bioaccumulative (U.S. EPA, 1995b).

The ERA development of potential ecological risks consisted of relating the exposure point concentrations in site soil to concentrations of these chemicals that are known to cause adverse effects. To characterize risks to terrestrial life, computed mean daily dose rates were compared to screening-level benchmarks for each terrestrial receptor of concern (i.e., deer mouse, herring gull, painted turtle, and American robin). The ERA's conclusions drawn from these comparisons, the evaluation of the data, and the site setting were as follows:

- Contaminants associated with surface soils that may pose a risk to terrestrial communities associated with the site are dibenzo(a,h)anthracene, lead, and mercury.

- The presence of nesting birds (herring gulls) on the site and endangered and threatened species near the site may require additional monitoring and evaluation.

Dibenzo(a,h)anthracene is a cPAH and shall be managed to protect human health. Examination of Table 4-2 in the ERA also reveals that while lead and mercury were identified as potentially of concern, the potential ecological risks were not high enough to warrant a detailed ecological risk assessment. This conclusion is consistent with the low potential effects found for these parameters in the HHRA. Consequently, no additional COCs or RAOs are proposed based on the ERA analysis.

3.2.3 Consideration of ARARs for Soil

CERCLA requires that RAOs comply with ARARs under federal environmental laws and state environmental laws or facility siting laws, or provide grounds for seeking a waiver of the requirement. In addition to ARARs, other advisories, criteria, or guidelines may be considered in developing RAOs, as appropriate.

ARARs can be classified as chemical-specific, location-specific, and action-specific. Potential chemical-specific and location-specific ARARs (for both soil and groundwater) are listed in Tables 3-1 and 3-2, respectively. Action-specific ARARs (e.g., Resource Conservation and Recovery Act [RCRA] and Clean Air Act [CAA]) are linked to specific remedial actions, and will be addressed in the context of detailed remedy evaluations in Section 5.

The WCP utilized coal to produce artificial gas and coke. This manufacturing process is typical and well understood. Byproducts and residues from this manufacturing process are a concentrated mixture of PAH materials found in coal.

The WCP byproducts and residues are not subject to direct RCRA regulation. The tar residues do not result from any RCRA-listed manufacturing processes. Similarly, WCP-produced tar is not a specifically listed commercial chemical product. This result is not surprising since the WCP manufacturing processes are moribund and RCRA typically focuses on current processes. Since 1988, the US EPA has not administratively acted to manage gas plant/coking residues as RCRA-listed wastes at other federally managed gas plants (e.g., Dubuque, Iowa; Decorah, Iowa; Taylorville, Illinois; Columbia, Missouri; Clinton, Missouri; Sedalia, Missouri; and Lawrence, Kansas). The recent land ban regulations reaffirm EPA's decision to not regulate manufactured gas/coking residues (see 63 Fed. Reg. 28556, 28574-75 (May 26, 1998)).

The soil at the WCP site is not a RCRA hazardous material. However, if a portion of the soil is removed from the site for treatment, this soil may need to be tested to determine if it exhibits any hazardous characteristics. The potential application of this action-specific ARAR is also described in Section 5.

3.2.3.1 Chemical-Specific ARARs for Soil

The State of Illinois has adopted a Tiered Approach to Corrective Action Objectives (TACO) (IEPA, 1997). For the FS, the Illinois TACO Rules are to be considered (TBC) criteria for soil. This regulation describes three tiers representing different procedures that can be used to develop risk-based and site-specific cleanup criteria. Tier 1 uses generic, conservative cleanup objectives, summarized in lookup tables, which can be used to evaluate the need for remedial action. Tier 2 provides for use of site-specific soil and groundwater information in standard risk formulas, with conservative exposure assumptions, for development of cleanup levels. Tier 3 is a site-specific risk assessment, with site-specific exposure scenarios. The HHRA and ERA represent an initial step in a Tier 3 analysis for the site. The site-specific soil PRGs and TSCs developed in this section represent Tier 3 calculations to assess risks for site-specific land use and exposure conditions.

3.2.3.2 Location-Specific ARARs for Soil

Location-specific ARARs are those requirements that relate to the geographical position of the site. The location-specific requirements currently identified as potential ARARs are listed in Table 3-2.

3.2.4 Development of TSCs

TSCs have been calculated to determine a potential cleanup action level that will be protective of human health and the environment. The TSCs have been calculated for unrestricted residential land use scenarios using the RME and CTE exposure scenarios, and for non-residential future land use scenarios using representative high exposure scenarios presented in Appendix 3-B. The primary emphasis for these TSCs is to assure protection for chronic exposures over the corresponding exposure domains, and for acute exposures at any point. A TSC is also developed to protect groundwater from potential impacts due to migration of residual materials in soil (Appendix 3-C). Section 4 of this report uses the TSCs and PRGs calculated in this work for the purpose of evaluating the effectiveness of potential remedial actions.

3.2.4.1 TSCs for Protection of Human Health

In developing the TSCs, the NCP defines an acceptable excess carcinogenic risk to human health as generally "an excess upper bound lifetime cancer risk to an individual of between 10^{-4} and 10^{-6}." The TSCs have been calculated for the future non-residential land use scenarios, which were developed for the HHRA and have been supplemented with scenarios that represent high but credible exposures for future commercial/industrial property use and extensive utility construction. The TSCs are representative of the reasonable high-exposure scenarios presented in Appendix 3-B for the COCs identified earlier. Using these scenarios, the target 10^{-5} concentrations of PCBs are greater than the highest observed concentration at the site, 38 mg/kg. Sampling for PCBs was directed toward those site locations most likely to exhibit elevated concentrations, so PCBs are not considered further for RAO development.

The soil risk values are summarized in Table 3-3. These include the PRG exposure scenarios calculated in the HHRA and the TSCs calculated using the RHE exposure scenarios. The concentrations in Table 3-3 represent average concentrations over an exposure domain to provide the level of protection indicated. For industrial/commercial development, the representative high exposure scenarios are the most reasonable guide to the concentration "targets" for evaluating the ability of remedial actions to protect human health and the environment. The RME and CTE values are more oriented toward exceptionally high exposure anomalies, and while valuable as screening values, they do not provide reasonable values for assessing the effectiveness of potential remedial actions. However, the completed remedy should be expected to be protective within the NCP risk range even for the RME and CTE scenarios over their exposure domains.

For the RHE scenarios considered (utility worker and industrial/commercial), the utility worker scenario has the lowest allowable concentrations. Since both of these scenarios were developed with similar conservatism in the estimation of exposures, the utility worker scenario represents the potentially critical exposure pathway that would need to be evaluated when considering the need for remedial actions. The values associated with residential land use scenarios were developed consistent with RME scenarios.

3.2.4.2 TSCs for Protection of Groundwater

RAOs were also developed for the soil-to-groundwater pathway. As explained in the RI, there is no current or ongoing source within the vadose zone soil that would account for the COC concentrations in the deep portion of the sand aquifer. Therefore, the TSC development focused on elimination of unacceptable deterioration of the shallow portion of the sand aquifer. The RI found that arsenic in the soil may influence groundwater quality in the shallow portion of the sand aquifer. For this reason, a site-specific correlation between the concentration of total arsenic in the soil and the shallow portion of the sand aquifer was developed in Appendix 3-C. This correlation was then used to calculate an arsenic TSC of 25 mg/kg based on protection of the shallow portion of the sand aquifer using a Class I standard of 0.05 mg/L. This value is consistent with the Illinois TACO Tier I value of 29 mg/kg for protection of Class I groundwater. Appendix 3-C also presents a summary of the soil screening values to protect groundwater for other parameters that have been identified in the shallow groundwater above the Class I standard using the Illinois guidance for calculation of site-specific standards.

3.3 Development of RAOs for Groundwater

For groundwater, the remedial action objectives are to:

- Protect human health by eliminating exposure (direct contact, ingestion, inhalation) to groundwater with concentrations of contaminants in excess of regulatory or risk-based standards.

- Protect the environment by controlling the off-site migration of contaminants in the groundwater to surrounding surface water bodies which would result in exceedance of ARARs for COCs in surrounding surface waters.

The review of the conclusions from the HHRA, ERA and ARARs with respect to groundwater RAOs are discussed below. Groundwater RAOs have been established in accordance with the unique setting of the WCP site.

3.3.1 Consideration of HHRA for Groundwater and Surface Water

The groundwater exposure scenarios evaluated for the HHRA included the potential for unrestricted residential or occupational use of the onsite groundwater. Chronic risks from future consumption of groundwater were not presented since the HHRA indicated that there were acute risks which outweighed the chronic or carcinogenic risks associated with consumption of the groundwater.

As noted in Appendix 3-A, non-residential land uses are considered the most likely future land uses for evaluating potential remedial actions for the WCP site. The HHRA concluded that ingestion of contaminated groundwater by industrial users would pose an acute risk to human health. Although this risk is limited because the exposure path is not currently available and would not reasonably be expected in the future, the RAOs for groundwater will include protecting future workers by preventing ingestion.

3.3.1.1 Utility Worker Exposure to Groundwater

The HHRA evaluated exposure of utility workers to site groundwater during subsurface construction activities. The HI for this scenario was less than 1, and the carcinogenic risks were less than 10^{5} for the RME case, and were less than 10^{-6} for the CTE case. Protection of utility workers from potential future exposure to shallow groundwater is included in the development of the RAOs for soil and groundwater at the site.

3.3.1.2 Exposures Related to Surface Water

For surface water, the HHRA evaluated potential risks to human health from either current or future consumption of fish from either Waukegan Harbor or Lake Michigan and from current or future swimming in Lake Michigan. None of the swimming scenarios identified any carcinogenic risks in excess of 10^{-6} or noncarcinogenic risks with an HI greater than 1. Carcinogenic risks for current and future subsistence fish consumption scenarios estimated in the HHRA were on the order of 10^{-6}. However, in preparing new Great Lakes surface water quality standards, the EPA judged that a less conservative exposure scenario than used in the HHRA should be applied to evaluation of fish consumption. Using these new Great-Lakes-specific exposure variables results in a total carcinogenic risk to human health due to subsistence fishing of much less than 10^{-6}. Details for these revised calculations are presented in Appendix 3-D. Consequently, no specific RAO is proposed to protect human health from potential carcinogenic risks from subsistence fish consumption.

3.3.2 Review of ERA for Protection of Groundwater and Surface Water

The ERA did not consider any potential impacts to groundwater. For surface water, the ERA evaluated risks to aquatic life by comparing criteria for the protection of aquatic life (FAWQC, Great Lakes Water Quality Criteria, or Illinois ambient water-quality criteria) to surface water concentrations. The surface water concentrations used were observed concentrations for current exposure scenarios and modeled concentrations for future scenarios. The modeled concentrations were based on surface water mixing with groundwater using the RI models for Waukegan Harbor and Lake Michigan. The ERA's conclusions from the evaluation of the site setting and from the comparisons of aquatic life criteria and observed or modeled surface water concentrations were as follows:

- The current and likely future habitat within the harbor "already precludes the existence of a diverse and sustainable population of aquatic organisms" (U.S. EPA, 1995b).

- For the harbor, "the presence of cadmium, 2-methylphenol, 2,4-dimethylphenol, 4-methylphenol, anthracene, and phenol are of greatest concern to aquatic organisms." However, "actual damage to the aquatic environment by cadmium, 2-methylphenol, 2,4-methylphenol, 4-methylphenol, and anthracene is probably negligible." Finally, "2-methylphenol and phenol may pose probable ecological damage in the form of chronic effects to the aquatic system" (U.S. EPA, 1995b).

The surface water quality standard for Lake Michigan Basin waters, promulgated after the ERA was performed, encompasses both 2-methylphenol and phenol. Further, as noted above, the ERA aquatic community considerations are of limited applicability to the harbor. Thus, based on the ERA and surface water quality standards, no additional RAO is proposed specifically to protect aquatic organisms.

3.3.3 Consideration of ARARs for Groundwater and Surface Water

Numerous potential chemical-specific ARARs have been promulgated by both the federal and state governments for groundwater and surface water. The potential chemical-specific ARARs are summarized in Table 3-1. The following sections address the potential application of these ARARs in accordance with regulations promulgated by the State of Illinois for addressing groundwater at contaminated sites.

3.3.3.1 Groundwater

3.3.3.1.1 Federal Standards for Groundwater

The Safe Drinking Water Act (SDWA) established maximum contaminant level goals (MCLGs). MCLGs set at levels above zero are potential ARARs for current or potential sources of drinking water. MCLGs set at zero are not relevant or appropriate to the circumstances of the site (as outlined in 40 CFR 300.400(g)(2)). The Maximum Contaminant Level (MCL) is the potential ARAR. MCLs and MCLGs above zero are summarized in Table 3-4 for contaminants at the WCP site.

3.3.3.1.2 State Standards for Groundwater

The Illinois Administrative Code (IAC) establishes Groundwater Quality Standards (GQS) for four groundwater classes (35 IAC 620.201):

- Class I: Potable Resource Groundwater
- Class II: General Resource Groundwater
- Class III: Special Resource Groundwater
- Class IV: Other Groundwater

Chemical-specific standards for Class I and Class II groundwater are summarized in Table 3-4. The Class I standards apply to groundwater greater than 10 feet below the land surface and within an aquifer with a reasonable yield (35 IAC 620.210). Class II groundwater standards apply to groundwater which is capable of agricultural, industrial, recreational or other beneficial uses and is less than 10 feet below the ground surface (35 IAC 620.220). Class III standards apply to groundwater which is demonstrably unique (35 IAC 620.230). The WCP site groundwater has not been designated a Special Resources Groundwater. Class IV groundwater standards apply to groundwater within a zone of attenuation and a point of compliance (35 IAC 620.240). Class IV also includes groundwater which has been designated as an exempt aquifer. For this FS it has been assumed that the sand aquifer is classified as Class I groundwater.

3.3.3.1.3 State Regulations for Contaminated Sites

From a practical standpoint, the attainment of Class I standards or MCLs is technically impracticable for the full extent of site groundwater in the immediate future. A number of approaches may be considered for the interim. Illinois 35 IAC 620.450 provides rules for establishing Alternative Groundwater Quality Standards (AGQS) as long as the exceedance has been minimized to the extent practicable, and any threat to public health or the environment has been minimized.

Similarly, site-specific risk-based levels can be defined under Illinois TACO rules, including 35 IAC 742.800(a).

The IAC Part 740, Section 740.530 provides for the automatic establishment of a Groundwater Management Zone (GMZ) for approved remedial action plans. These rules are TBC criteria for the WCP site. A GMZ (35 IAC 620.250) is established for groundwater being managed to mitigate impairment caused by the release of contaminants from a site. Alternative groundwater standards are applied to a GMZ. During the period of groundwater management, the groundwater within a GMZ is exempt from the Class I through IV standards. After remediation, concentrations within a GMZ may exceed the groundwater standards if, to the extent practicable, the exceedance has been minimized and beneficial use has been returned and any threat to public health or the environment has been minimized. Groundwater may also be reclassified by petition to the Illinois Pollution Control Board. The reclassification procedure is outlined in 35 IAC 620.260.

3.3.3.2 Surface Water

3.3.3.2.1 State of Illinois Water Quality Standards

Illinois Water Quality Standards (IWQS) are promulgated as part of the Illinois Water Pollution Control Rules (35 IAC Subtitle C, Part 302). On December 18, 1997, the Illinois EPA filed the adopted rule final order for the purpose of conforming Illinois rules with the Great Lakes Initiative (GLI). This rulemaking defines water quality standards for Lake Michigan Basin waters ("Basin Waters"), which are intended for harbors, breakwater areas, and tributaries. "Open Waters" standards, on the other hand, apply to the body of Lake Michigan. Table 3-5 shows the "Open Waters" and "Basin Waters" standards for Lake Michigan. Also shown are the Subpart C standards applicable to public drinking water supplies. The "Open Water" standards and the Subpart C standards apply to the City of Waukegan water supply intake located about 6,000 feet out in the lake. Figure 3-1 illustrates the areas for "Open Waters" standards and for "Basin Waters" (harbor and breakwater areas) standards in the vicinity of the site, as defined by IEPA in an April 15, 1998 meeting with representatives of the U.S. EPA, North Shore Gas, and General Motors.

The surface water standards in Table 3-5 include criteria for phenols and ammonia. The 1997 surface water sampling (Section 2) identified the presence of ammonia and phenol near the shore of Lake Michigan but away from the WCP site at concentrations similar to those detected in the vicinity of the WCP site. The widespread presence of these constituents in the water of Lake Michigan make these criteria impractical for evaluating site-specific impacts. Appropriate site-specific criteria may be determined during the design phase.

3.3.3.2.2 Federal Ambient Water Quality Criteria

In addition to the State of Illinois rules, FAWQC established under Section 303 or 304 of the Clean Water Act (CWA) for priority pollutants may be relevant and appropriate, depending on the circumstances of the site (40 CFR 300.430(e)(2)(i)(E)). FAWQC for human health are promulgated for exposures that include (1) drinking water and consuming fish and (2) consuming fish only. FAWQC are also promulgated for aquatic life protection. The FAWQC are listed in Table 3-5.

At the time of the development of the FAWQC for aquatic life protection, sufficient data were not available to derive aquatic life criteria for all of the priority pollutants. Therefore, the lowest report effects levels (LRELs) available in the scientific literature for these chemicals were published in lieu of criteria. The LREL would be TBC.

3.3.4 Development of Site-Specific Groundwater RAOs

RAOs have been developed for the shallow portion of the sand aquifer concurrently with the development of the second RAO for soil. By managing or eliminating the potential sources of contamination to the shallow portion of the sand aquifer, the soil RAOs also address this zone.

As detailed in Appendix 3-E, meeting the NCP goal of cleaning the deep portion of the sand aquifer to MCLs or Class I standards is technically impracticable. Consistent with EPA policy (USEPA, 1993, and USEPA, 1998b), when attainment of MCLs is technically impracticable, the Alternative Remedial Strategy is to:

- prevent exposures
- control sources
- minimize migration
- reduce the area of impact

As explained in Section 2, the sources responsible for the current impacts to the deep portion of the sand aquifer have been removed, so the second item of the Alternative Remedial Strategy is complete. The following paragraphs develop site-specific groundwater RAOs to meet the other items required for an alternative remedial strategy.

3.3.4.1 Groundwater RAO to Prevent Exposures

As discussed previously, the current concentrations of the contaminants of concern in the groundwater represent a potentially acute threat to human health if consumed. However, consumption of groundwater is an incomplete exposure pathway because no drinking water wells exist on the Waukegan Harbor peninsula or in its immediate vicinity. Drinking water is available from the municipal water supply. The first RAO for groundwater is to manage site uses to prevent any future direct exposure to groundwater where groundwater from the site exceeds drinking water standards.

3.3.4.2 Groundwater RAO to Minimize Migration

As explained in Section 2, the site groundwater migrates from the peninsula to the lake and harbor. It follows then that protection of the surface water quality should be the purpose of minimizing groundwater migration. Two basic approaches can be used to minimize potential future impact to surface water—reducing driving forces (the hydraulic gradient) on the groundwater, and reducing the mass or concentration within the plume. This RAO will address reducing the driving force; the next RAO will address reducing the mass.

Reducing the driving force on the plume can be accomplished by reducing infiltration over the peninsula. This would slow the velocity of groundwater flow and thereby reduce the mass flux to the surface water. Appendix 2-D estimates the effect of the current mass flux from groundwater to surface water. That analysis shows that maintaining the mass flux to the harbor and breakwater areas is protective of the surface water quality. Reducing the mass flux by slowing groundwater discharge to these areas would provide an additional factor of safety for these waters. The RAO to secure that protective condition is to protect surface water quality by reducing the driving forces on groundwater at the site.

3.3.4.3 Groundwater RAO to Reduce the Area of Impact

Reducing the area of impacted groundwater can be accomplished by controlling the direction of groundwater flow or by removing mass from the impacted area. At the WCP site, the most effective way to accomplish this is to focus on removing mass from the area of highest concentration. Appendix 3-F describes the areas to target in order to accomplish effective mass reduction. Mass removal is particularly relevant to the area of the plume that discharges to the Open Waters Standards area of Lake Michigan as shown on Figure 3-1. The site-specific groundwater RAO for reducing the area of impact is to protect surface water quality by reducing the mass of COCs within the areas of impacted groundwater that can be expected to produce exceedances of surface water standards.

3.4 Remedial Action Objectives Summary

The overall remedial action objectives are to:

- Protect human health by eliminating exposure to soil with concentrations of contaminants which may represent an excess carcinogenic risk to human health using $1x10^{-6}$ as a point of departure and an HI greater than 1 for reasonably anticipated future land use scenarios.

- Protect human health by eliminating exposures (direct contact, ingestion, inhalation) to groundwater with concentrations in excess of regulatory or risk-based standards.

- Protect the environment by controlling the off-site migration of contaminant in the groundwater to surrounding surface water bodies which would result in exceedences of ARARs for COCs in surrounding surface waters.

Using these overall objectives, site-specific TSCs for soil and site-specific RAOs for groundwater have been developed. These TSCs and RAOs address the site setting, existing and future land use, existing and future groundwater use constraints, constraints imposed by the adjacent Waukegan Harbor Superfund site, federal and state ARARs, as well as the site human health and ecological risk assessments for the site.

Soil RAOs are:

- Protect future workers by reducing arsenic, cPAHs, and other COCs in the soil to acceptable concentrations or by eliminating exposures.

- Protect the environment by minimizing/eliminating the migration of contaminants in the soil to groundwater or to surrounding surface water bodies.

The RAOs for groundwater are:

- Manage site uses to prevent any future direct exposure to groundwater where groundwater from the site exceeds drinking water standards.

- Protect surface water quality by reducing the driving forces on groundwater at the site.

- Protect surface water quality by reducing the mass of COCs within the areas of impacted groundwater that can be expected to produce exceedences of surface water standards.

4.0 Development and Screening of Alternatives

4.1 Introduction

This section presents the development and screening of potential remedial action alternatives for the WCP site. The evaluation is consistent with the information presented in Sections 2 and 3, along with EPA guidance. A broad range of potential remedial actions is considered. In accordance with NCP requirements and EPA guidance, the process of developing and screening alternatives includes (EPA, 1988b):

- Identifying general response actions capable of meeting the site-specific remedial action objectives.
- Identifying the volumes and areas of the affected media.
- Screening technologies and/or process options.
- Assembling site-wide alternatives using combinations of remedial technologies or process options to address all affected media.
- Screening alternatives based on the general parameters of effectiveness, implementability, and cost.

Alternatives that do not meet specified objectives are eliminated, while others are retained for the detailed analysis. The detailed analysis is presented in Section 5.

4.2 Development of General Response Actions

General response actions are broadly defined as: actions that can be used to remediate the impacted media at a given site. General response actions are evaluated to determine whether they meet the site RAOs (Section 3). The following general response actions are evaluated for the impacted media at the WCP site.

For vadose zone soil:

- No action
- Routine monitoring
- Institutional controls
- Containment
- Excavation and disposal
- Excavation and treatment
- In-situ treatment

For groundwater:

- No action
- Monitoring
- Institutional controls
- Monitored natural attenuation
- Groundwater extraction
- Groundwater migration control/containment
- Ex-situ treatment
- In-situ treatment
- Treated groundwater discharge

Each of these general response actions includes one or more remedial technologies or process options that will be screened in order to develop alternatives for the WCP site.

4.3 Identification of Areas and Volumes of Impacted Media

4.3.1 Soil Remediation Zones

The goals of the vadose zone soil remedial actions are:

1. Protect future workers by reducing arsenic, cPAHs, and other COCs in the soil to acceptable concentrations or by eliminating exposures.

2. Protect the environment by minimizing/eliminating the migration of contaminants in the soil to groundwater or to surrounding surface water bodies.

To achieve these goals, the impacted vadose zone soils will be grouped into Remediation Zones by contaminant or media types. The Remediation Zones will be analyzed by risk level and by soil to groundwater pathway considerations to develop areas and volumes of media for remediation. The Remediation Zones will then be refined for use in the identification and screening of technologies and process options and eventually for the development of alternatives.

4.3.1.1 Protection of Human Health

As discussed in Section 3, both the RME and CTE exposure assumptions produce values which would be considered preliminary remediation goals (PRGs). In accordance with EPA guidance, PRGs are intended as conservative screening values to be used in preliminary decisions regarding the need for and extent of investigative efforts or remedial measures. As such, the RME and CTE values were calculated using conservative assumptions.

When evaluating the need for long-term remedial actions, as in this feasibility study, the PRGs calculated using RME and CTE exposure scenarios may be overly conservative. Therefore, to evaluate the protectiveness of proposed remedies, target soil concentrations (TSCs) were calculated in Section 3. The TSCs are based on an updated exposure scenario that reflects modern practices in commercial and industrial land development. The exposure scenario used to develop the TSCs is considered a representative high exposure (RHE). The development of the RHE exposure scenario is presented in Appendix 3-B.

Soil remediation zones will be based on the RHE exposure scenario. A risk level range of 10^{-4} to 10^{-6} is used during the FS process. Soil or source material exceeding 10^{-4} is generally removed or treated. Soil exceeding 10^{-6} is generally capped or managed to minimize exposure. In order to assure a high level of protection, this FS uses a 10^{-5} RHE threshold for removal/treatment. This is a very protective risk level assumption to use for site soils based on current and future land use scenarios and remedial action objectives developed in Section 3.0. As discussed later in this Section, this exposure scenario will be protective of human health to much lower risk levels.

4.3.1.2 Soil to Groundwater Pathway

As discussed in Section 3, the TSC development focused on elimination of unacceptable deterioration of the shallow portion of the sand aquifer. The RI found that arsenic in the soil may influence groundwater quality in the shallow portion of the sand aquifer. For this reason, a site-specific correlation between the concentration of total arsenic in the soil and the shallow portion of the sand aquifer was developed in Appendix 3-C. This correlation was then used to calculate a soil arsenic

TSC of 25 mg/kg based on protection of the shallow portion of the sand aquifer using an Illinois Class I standard.

Other COCs for protection of the groundwater include carbazole and naphthalene. Both of these compounds are naturally biodegradable and have not produced deteriorated water quality the way arsenic has in the shallow portion of the sand aquifer. PCBs are another COC for protection of the groundwater. PCBs have not produced deteriorated water quality in the shallow groundwater and are very insoluble.

4.3.1.3 Definition of Media and Volumes

From the protection of human health exposure scenarios and the soil to groundwater pathway the vadose zone soil can be divided into three zones: (1) the Arsenic Remediation Zone; (2) the PAH Remediation Zones; and (3) the Marginal Zones. Soil volumes associated with each of the exposure scenarios and the soil to groundwater pathway for the remediation zones are shown in Table 4-1. The limits of the remediation zone associated with the soil to groundwater pathway is represented by the soils in the Marginal Zones.

Future residential land use at the site typically requires a protective target soil concentration. At the 10^{-6} excess cancer risk level, residential land use would require protection from exposure to any soil at the site, a volume in excess of 200,000 cubic yards (RME scenario) with costs estimated at $25,000,000 or greater. As discussed in Section 3 (Appendix 3-A), residential land use is not the reasonably anticipated future land use for the site. Consequently, no remedial alternatives based on future residential land use are proposed.

Commercial/industrial land use is the reasonably anticipated future land use at the site. In order to achieve a practical, protective soil remedy for the site, the volume of soil to manage, and the forms of management, were evaluated based on protection of groundwater risk and mass removal effectiveness.

Protection of groundwater can be effectively accomplished by capping, soil removal or a variety of other technologies. The area to manage for protection of groundwater is approximately 16 acres, corresponding to a total of 90,000 cubic yards, based on the 25 mg/kg arsenic threshold. This is the largest area and volume to manage for all but the most extreme commercial/industrial scenario (the 10^{-6} RME case).

Aggressive management, such as excavation and treatment, or secure containment, is generally appropriate for the highest concentration, potential "source" materials at a site. The volume for aggressive management for the WCP site was determined using the mass vs. volume relationships shown on Figures 2-8 (PAHs) and 2-9 (arsenic). For PAHs, the incremental mass removed becomes small for soil volumes in excess of about 7,000 cubic yards. Consequently, a PAH remediation zone volume of 7,100 cubic yards is used in potential aggressive management technologies.

An area of elevated arsenic concentration, about 3,300 cubic yards, is present near the high PAH concentration area. This is the volume used for screening potential aggressive arsenic management technologies.

Figure 4-1 shows the Remediation Zones represented by the RHE non-residential exposure scenario. These areas would be expanded by using the more conservative exposure scenarios. The residential RME exposure scenario would include the entire site. As shown on Figure 4-1, the Arsenic and PAH Remediation Zones represent the estimated extent of the zones where the concentrations of arsenic and PAHs pose a carcinogenic risk of 10^{-5} or greater using the RHE utility worker exposure scenario. The Marginal Zones are generally situated around the remediation zones, where the soils may pose a carcinogenic risk in excess of 10^{-5} or contain arsenic in excess of 25 mg/kg for the soil-to-groundwater pathway.

To further refine and to address the sensitivity of the volumes associated with the RHE exposure scenario, the PAH Remediation Zones represent an estimated in-place soil volume of between 7,100 and 14,900 cubic yards (CY). The Arsenic Remediation Zone on Figure 4-1 is estimated to be between 3,300 cubic yards and 7,200 cubic yards. Table 4-1 summarizes these volume estimates. The range of volume estimates in Table 4-1 for the PAH Remediation Zone is based on representative and high interpretation of tarry soil limits observed during the investigation. The range of volume estimates in Table 4-1 for the Arsenic Remediation Zone soil is based on interpolation between observed data points. For the representative volume, a linear interpolation between analytical data points was used. For the high volume the limits were estimated using a non-linear distribution between observed data points which was skewed in favor of the higher concentrations. The volume of Marginal Zone soil is 90,000 cubic yards. Evaluation of the site data shows that effective management of 7,100 cubic yards of the highest concentrations of PAHs addresses almost 90 percent of the total mass of PAHs at the site.

Due to the absence of unacceptable risk posed by the soil in the temporary dredge spoil stockpile, the soil will be used as a clean fill material during remediation

4.3.1.4 Regulatory Status of Target Materials

As discussed in Section 3.2.3, the waste at the site is not listed hazardous waste. If waste is hazardous, it would be so on the basis of a hazardous characteristic. TCLP testing was performed on two samples of tarry soil, one of coal, and two of sediments from former pond areas. The full test results are shown in the RI, Table 4.6.4. For the two samples of tarry soil, no parameters were within an order of magnitude of the regulatory thresholds except benzene. One sample was reported to have 720 µg/L, the other 180 µg/L benzene, compared to the regulatory level of 500 µg/L. The lower benzene result is expected to be typical of the tarry soils at the site, as little benzene was detected in vadose zone soil samples. In the Remedial Design, an assessment will be made to identify areas with the potential to require special management to address TCLP benzene issues.

The TCLP testing of coal reported no detected concentrations of any parameters except barium (832 µg/L and 876 µg/L) and cadmium (<5 µg/L and 6.3 µg/L). These two detections are far below the regulatory thresholds of 100,000 µg/L (barium) and 1,000 µg/L (cadmium).

Neither of the samples from the sediments from former pond areas were reported to have any parameters exceed TCLP regulatory thresholds. One sediment sample, despite an oily appearance, had only an estimated 5 µg/L benzene concentration (regulatory threshold 500 µg/L), and a reported 731 µg/L arsenic concentration (regulatory threshold 5,000 µg/L). The other sediment sample was reported to have no detected benzene or arsenic.

This testing illustrates that there is likely to be little material at the site which has the potential to exceed regulatory thresholds and be classified as characteristic hazardous waste. The limited areas with such potential will be identified during Remedial Design so that special management procedures can be applied to these materials.

4.3.1.5 Effectiveness of Soil Remediation Zone Selection Based on Preliminary Evaluation of Proposed Excavations

Post-excavation confirmatory samples will be collected and analyzed according to a statistically based random procedure described in Appendix 4-A. The attainment of soil RAOs will be assessed by computing the upper confidence limit (UCL) of the mean of constituents of concern over appropriate exposure domains centered around various remediation zones, consistent with U.S. EPA guidance. The exposure domain is the land area associated with the exposure scenario. In the development of the HHRA, EPA implicitly used exposure domains of approximately 5 to 7 acres. For future scenarios, the exposure domain used in risk analysis is 5 acres for industrial/commercial scenarios, and 2 acres for utility worker and construction scenarios. For a property such as the WCP site, an exposure domain of 5 acres represents a conservatively small domain for commercial/industrial development. An exposure domain of 2.5 acres was also analyzed in Appendix 4-A. As a preliminary evaluation, the attainment of soil removal RAOs is simulated for each exposure domain designated in Appendix 4-A. The evaluation showed that the delineated removal actions not only will satisfy RHE risk values to 10^{-5}, but also meet the highly conservative RME risk values. Management of these soil volumes will be protective for future commercial/industrial use of the site.

4.3.2 Groundwater Remediation Zones

The goal of the remedial actions for groundwater and protection of surface water are to:

- Manage site uses to prevent any future direct exposure to groundwater where groundwater from the site exceeds drinking water standards.

- Protect surface water quality by reducing the driving forces on groundwater at the site.

- Protect surface water quality by reducing the mass of COCs within the areas of impacted groundwater that can be expected to produce exceedences of surface water standards.

The site-specific groundwater remedial action goals from these RAOs are contaminant mass reduction for discharge to Lake Michigan and flux management for the harbor. To pursue these goals, the impacted site groundwater is divided into two discharge areas: (1) impacted groundwater discharging toward the open water portion of Lake Michigan; and (2) impacted groundwater discharging toward the harbor and the breakwater area.

The Illinois Groundwater Protection Act and its implementing regulations (Ill. Adm. Code 620.250, 620.260, 620.450) allow the owner or operator of a site which exceeds Illinois groundwater quality standards for its groundwater class to obtain a groundwater management zone (GMZ) and perform remedial activities until:

- The site achieves compliance with the applicable groundwater quality standards (Ill. Admin. Code 620);

- At the completion of the remedy, if groundwater quality standards for its groundwater class are exceeded, Ill. Adm. Code 620.450(a)(4)(B) establishes a mechanism for setting groundwater quality restoration standards, provided 1) the exceedance has been minimized to the extent practicable and groundwater has been returned to beneficial use as appropriate for the groundwater class and 2) any threat to public health or the environment has been minimized; or

- In response to a petition for relief, the Illinois Pollution Control Board issues a site-specific rule or adjusted standard.

To achieve the above goals, a GMZ may be requested for the impacted groundwater. The provisions for a GMZ are voluntary and are for areas which exceed groundwater standards and where the remedy is in the process of mitigating impairment. The manner in which the selected remedies mitigate groundwater impairment is addressed in Section 5.

4.3.2.1 Groundwater Treatment Remediation Zone Selection

The analysis of groundwater discharge to surface water in Section 2 and Appendix 2-D showed that the discharge of site groundwater to surface water does not result in exceedance of surface water quality standards in those areas where Lake Michigan Basin water quality standards are applied (the harbor and breakwater areas). For groundwater discharging to the open waters of Lake Michigan directly east of the site (the Lake), a site-specific groundwater RAO to reduce the mass within the area of impacted groundwater will be applied.

The area of impacted groundwater that discharges to the Lake has the potential to cause exceedences of surface water standards. Within this area, the zone where mass reduction will be beneficial is defined by the proportion of COC mass addressed in relation to the effort expended. The details of this process are in Appendix 4-B. The preliminary target area for groundwater remediation is defined by the 20 mg/L arsenic contour as shown on Figure 4-2, 4-3 and 4-4. This area combines the highest arsenic, phenol, and ammonia concentrations as discussed in Appendix 4-B. Addressing the groundwater contamination in this area will protect the lake from likely exceedences of surface water standards.

The delineation of the treatment zone on the beach is preliminary and will be further defined after additional investigation during remedial design. Additional investigation is likely to include sampling of groundwater along a north-south transect on the beach.

Additional groundwater investigation south of Slip No. 4 will be conducted during remedial design on the harbor side to determine if and where additional treatment may be necessary.

4.4 Identification and Screening of Technologies and Process Options

In accordance with EPA guidance, three criteria are used to screen technologies and process options: effectiveness, implementability, and cost (U.S. EPA, 1988a). Tables 4-2 and 4-3 present the initial screening results for the possible technologies and process options identified for vadose zone soil and groundwater. Appendix 4-C provides further detail concerning the evaluated remedial technologies for vadose zone soil and groundwater. Appendix 4-D provides summaries on the results of the technology evaluation testing completed for soil and groundwater.

4.4.1 Effectiveness

The evaluation of effectiveness is based on the following factors: (1) the ability of a process option to remediate the COCs at the site; (2) the ability of the process option to function under the conditions specific to the WCP site; and (3) the potential for adverse impacts to occur during implementation of the process option. The U.S. EPA guidance document entitled *Contaminants and Remedial Options at Wood Preserving Sites* (U.S. EPA, 1992b) was used in assessing the degree of effectiveness of several treatment technologies and process options for COCs. Other references as footnoted on the tables and previous experience also were used to evaluate effectiveness.

4.4.2 Implementability

The implementability evaluation is based on technical and logistical feasibility. Technical implementability includes the status and performance of a technology for the given site conditions. Logistical feasibility is based on infrastructure and non-technical aspects of implementability, the availability of treatment, storage, and disposal services (including capacity), the availability of necessary equipment and skilled workers to implement the technology, and potential bottlenecks in securing acceptance for remedial technologies or security approvals for offsite actions.

4.4.3 Cost

The cost evaluation in Tables 4-2 and 4-3 shows approximate unit costs for application of each technology. The costs do not include associated functions such as site preparation, material preparation, or site restoration. Where technologies are not well-represented by a unit cost, the overall cost of implementation is characterized as low, medium, or high relative to other general response actions. At this stage in the screening process, the cost analysis is made on the basis of engineering judgement, and each process option is evaluated as to whether costs are high, low, or medium relative to other process options in the same technology type.

4.4.4 Evaluation Results

Evaluation results are shown in Tables 4-2 and 4-3. Those options that display certain characteristics are eliminated, including: (1) ineffectiveness; (2) non-implementability; (3) poorly suited to the site conditions, or (4) considerably more expensive than other alternatives within the same technology group.

The evaluation results also indicate that certain classes of general responses, remedial technologies and options must be combined in order to yield effective, implementable remedies at the WCP site. For example, ex-situ water treatment such as aerobic biological treatment must be combined with groundwater extraction and discharge processes in order to be implemented. Such effective, implementable, cost-efficient combinations are retained for further analysis.

4.5 Selection of Technologies and Process Options

Tables 4-4 and 4-5 present the technology and process options retained for the development of alternatives for vadose zone soils and groundwater, respectively. Development of the remediation alternatives consists of refining the general responses into site-specific responses, followed by assembling them into effective combinations. The following sections provide a detailed discussion of this process.

4.6 Development of Alternatives

This section outlines the approach used to combine the retained alternatives into specific alternatives for each media of concern. In the following discussions, alternative combinations are considered separately for each media.

4.6.1 Vadose Zone Soil

Vadose zone soil alternatives address remediation of: (1) the Arsenic Remediation Zone, (2) the PAH Remediation Zones, and (3) the Marginal Zones. The site-specific response actions for vadose zone soil include no action, institutional controls, cap, or excavation with onsite containment or offsite disposal, and treatment (both in-situ and ex-situ treatment process options are included under treatment). For each site-specific response action, one or more alternatives have been developed using one or more process options for the individual soil zones. The alternatives are shown in Table 4-6 and defined below.

- Alternative 1: No action.
- Alternative 2: Institutional controls, includes access restrictions and land use restrictions.
- Alternative 3: Asphalt cap or phytoremediation cap. Either of these options can be used to cover the soil remediation areas indicated on Figure 4-1.
- Alternative 4: Excavation and onsite or offsite disposal. Onsite disposal would involve construction of a vault designed consistent with RCRA Subtitle C requirements for PAH and Arsenic Remediation Zone soils and a cap for the Marginal Zone soil. The location of the vault would be determined based on anticipated future development of the property and integration with the groundwater remedy. For offsite disposal, the PAH and Arsenic Remediation Zone soils will be disposed of in either a RCRA Subtitle C or D landfill depending on whether the soil is classified as characteristically hazardous or based on landfill acceptance criteria. The Marginal Zone soil may be disposed of in a RCRA Subtitle C or D landfill or capped.
- Alternatives 5 through 7: Treatment alternatives for the PAH and Arsenic Remediation Zone soils. The Marginal Zone soils for these alternatives are capped, disposed offsite or treated.

(Refer to Table 4-6 for a summary of which process options are combined for each of the treatment alternatives.)

For the Arsenic Remediation Zone soil, stabilization/solidification is the most viable treatment technology and is used in all subsequent treatment alternatives. For the PAH Remediation Zone, thermal treatment technologies such as power plant co-burning or thermal oxidation/desorption (in-situ or ex-situ) are used in all subsequent treatment alternatives. These technologies are proven, viable alternatives for the PAH Remediation Zone soil. Co-burning the PAH Remediation Zone soil would likely require blending with coal, wood ash, or other materials in order to achieve satisfactory materials-handling characteristics. This technology has been demonstrated at full scale and approved for dealing with wastes from a Superfund site. Treatment of MGP soil will be conducted according to the Edison Electric Institute (EEI) strategy discussed in correspondence from the US.

EPA and an additional interpretive letter included in Appendix 4-E. These letters clarify the Phase IV land disposal restrictions on cleanup of MGP sites.

For the Marginal Zone soils, the following technologies are considered in Table 4-7, including: phytoremediation/asphalt cap; ex-situ chemical/biological treatment; stabilization/solidification; and thermal desorption. Phytoremediation is an innovative and promising technology. Phytoremediation acts as a cap to reduce risk of exposure to soils, restricts the movement of water soluble contaminants, increases organic carbon in the soil which reduces the mobility of organic contaminants, and potentially acts as an in-situ soil remediation system. Over several decades, phytoremediation has proven effective for remediation of total PAHs. It is anticipated that phytoremediation immobilizes and possibly degrades carcinogenic PAHs over time. Thermal desorption is a more costly technology and may require extensive permitting in Illinois, but is retained because of the demonstrated effectiveness of thermal desorption at many PAH sites. Of the biological treatment technologies, ex-situ treatment technologies such as composting, biopiles, and land treatment currently are unproven for treating PAH soils, unless an innovative approach such as chemical treatment is added to increase effectiveness. Biological treatment with chemical oxidation is retained after screening in Table 4-7.

4.6.2 Groundwater

The RAOs for groundwater are:

- Manage site uses to prevent any future direct exposure to groundwater where groundwater from the site exceeds drinking water standards.

- Protect surface water quality by reducing the driving forces on groundwater at the site.

- Protect surface water quality by reducing the mass of COCs within the areas of impacted groundwater that can be expected to produce exceedences of surface water standards.

The site-specific groundwater remedial action goals from these RAOs are contaminant mass reduction for discharge to Lake Michigan and flux management for the harbor. To pursue these goals, the impacted site groundwater is divided into two discharge areas: (1) impacted groundwater discharging toward the open water portion of Lake Michigan; and (2) impacted groundwater discharging toward the harbor and the breakwater area.

The goal of mass reduction is to reduce the mass of organic COCs (i.e., phenols, benzene, and BOD), thiocyanate, arsenic, and ammonia. Such reductions will also expedite the ongoing natural attenuation. Mass reduction can be achieved through a combination of contaminant removal and treatment, along with monitored natural attenuation.

The goal of flux management is to reduce the loading of COCs to surface water. Flux management includes combinations of capping, groundwater migration control/containment, and treatment technologies. The evaluated alternatives are shown on Table 4-7 and defined below.

- Alternative 1: No Action.

- Alternative 2: Monitored natural attenuation for the lake and harbor reduces the flux of COCs through existing natural processes. Natural attenuation includes a variety of aerobic and anaerobic biological processes, as well as physical and chemical processes. To implement this alternative for the entire site, a routine monitoring program would be established to monitor the concentration of the groundwater COCs to confirm the effectiveness of natural attenuation.

- Alternative 3: Infiltration-reducing cap would be placed on the site to manage the flux of groundwater. The cap would reduce the infiltration rate and reduce the flux of COCs to the harbor. The capped area can incorporate phytoremediation zones, consisting of communities of selected trees, bushes or shrubs. The plants restrict the offsite movement of water-soluble contaminants by (1) reducing net infiltration by water removal through plant transpiration, and (2) plant uptake and metabolism of contaminants in soil and groundwater. Monitored natural attenuation would be used for the lake in this alternative although it occurs across the entire site.

- Alternative 4: A vertical barrier, such as a slurry wall or sheet-pile wall, would reduce the contaminant flux to the harbor. If the slurry wall is installed as a closed wall, the infiltrated water must be pumped out of the wall area and treated. Prior to discharge to the Publicly-Owned Treatment Works (POTW), pretreatment including biological and chemical/physical treatment would be required. A cap would be placed with this alternative to reduce the volume of infiltrated water into the wall area.

- Alternatives 4 and 5: Cell-based extraction and treatment would be implemented within the highly impacted zones, including the beach area and the zone south of Slip No. 4. Cells would be implemented progressively from the downgradient margins toward the upgradient side of the impacted groundwater. Each cell would have a limited treatment area, where the removal process is enhanced thorough reinjection of treated water. The extraction rates would be at low levels to minimize upward mixing of contaminants. The ex-situ treatment system would be designed to remove organics (i.e., phenols, benzene, toluene ethylbenzene, xylene (BTEX) and Biochemical Oxygen Demand (BOD), thiocyanate, arsenic, and ammonia. After the termination of a cell operation, the recirculation system would be moved to a new upgradient location. After a predefined portion of the site has been treated, the remaining groundwater would be allowed to improve by natural attenuation.

- Alternative 6: Aquifer restoration consists of a pump-and-treat system to restore the groundwater to drinking water standards. This alternative aims to restore the aquifer by sustaining a sufficiently high pumping rate to draw water from the lake and harbor, thus flushing the aquifer. The extracted water would be pretreated and discharged to the POTW.

4.7 Assembling and Screening of Alternatives

The alternatives assembled in Table 4-6 (soil) and 4-7 (groundwater) are screened in Tables 4-8 (soil) and 4-9 (groundwater) based on the three U.S. EPA criteria of effectiveness, implementability, and cost. Cost comparisons are made based on total cost ranges using preliminary assumptions. The data used to develop the preliminary costs presented are included in Appendix 4-F. Appendix 4-F also includes a brief description of the alternative and the key assumptions used to develop the preliminary costs.

The costs shown in Tables 4-8 (soil) and 4-9 (groundwater) and Appendix 4-F are intended to be order-of-magnitude cost estimates as defined by the American Association of Cost Engineers. It is expected that the actual cost would be in the range of 50 percent higher to 30 percent lower than the order-of-magnitude estimate. In Chapter 5, detailed order-of-magnitude cost estimates are developed for each retained alternative.

Some of the general assumptions used for the cost estimates include the following:

- Representative soil volumes were used to develop vadose zone soil remedy cost estimates as shown in Table 4-1.

- Operation and maintenance costs are for 30 years at 5 percent interest unless stated otherwise.

- A sanitary sewer discharge cost of $4 per 1,000 gallons is used for cost estimating. For groundwater treatment alternatives with discharge to the local POTW, the North Shore Sanitary District (NSSD), the cost estimates are strongly influenced by discharge costs. NSSD has in the past and in recent conversations quoted discharge rates of $0.10 per gallon for water from remediation activities. Because this is an extraordinary cost, the NSSD would be petitioned for lower rates prior to selection of the alternative. Typical NSSD rates for high strength industrial wastewater discharges over an extended length of time are at $4 per 1,000 gallons. Because of these issues, a cost in between the $4 per 1,000 gallons and the $0.10 per gallon costs for estimates involving POTW discharges should be viewed as a more reliable estimate.

For the vadose zone soil, Alternative 2 (Institutional Controls) and Alternative 3 (Capping) are used in combination with other alternatives. Alternatives 6 and 7 were eliminated because they were not cost-effective compared to other treatment or containment alternatives, and did not offer significant risk reductions.

For groundwater, Alternatives 2 and 3 are used in combination with other alternatives. All other alternatives have been retained for analysis.

4.8 Remedial Alternatives

A wide variety of site-specific alternatives that satisfy the remedial action objectives are selected for further consideration. To enhance the effectiveness of the retained alternatives, they are combined into a number of "Remedial Alternatives," as shown in Table 4-10 and described below. With the exception of the no action alternative (Remedial Alternative 1), all the other remedial alternatives selected include soil and groundwater remedies that satisfy the site remedial objectives. These remedial alternatives are intended to take advantage of synergies associated with combining the vadose zone soil and groundwater alternatives. Such combinations of alternatives have mutually-reinforcing aspects that naturally integrate their benefits.

Remedial Alternative 1

The no-action alternative constitutes the absence of any remedial actions. No action is considered in this evaluation as a baseline for comparison to all other potential remedial actions as required by the NCP.

Remedial Alternative 2A

- Soil Alternative 5b: Treatment of PAH and Arsenic Remediation Zone soils and asphalt cap for marginal soils
- Groundwater Alternative 4: Asphalt cap, vertical barrier and treatment cells for harbor and lake, monitored natural attenuation

Remedial Alternative 2B

- Soil Alternative 4b: Excavation and disposal off-site in a RCRA Subtitle C landfill of PAH and Arsenic Remediation Zone soils and asphalt cap for marginal soils
- Groundwater Alternative 4: Asphalt cap, vertical barrier and treatment cells for harbor and lake, monitored natural attenuation

Remedial Alternative 2C

- Soil Alternative 4a: Excavation and disposal on-site in a containment unit of PAH and Arsenic Remediation Zone soils and asphalt cap for marginal soils
- Groundwater Alternative 4: Asphalt cap, vertical barrier and treatment cells for harbor and lake, monitored natural attenuation

With the exception of Alternative 1, each soil option includes excavation and either treatment or disposal, offsite or onsite for PAH and Arsenic Remediation Zone soils. Each of the soil and groundwater alternatives include capping. The cap coverage would be selected to accomplish the objectives for both soil and groundwater. Asphalt capping is used for minimizing infiltration into the wall area, limiting exposure to soil, reducing COC mobility in the soil to groundwater, and reducing the COC flux for groundwater. A slurry wall is used to reduce flux to the harbor. Treatment cells and monitored natural attenuation reduce contaminant mass to the lake and harbor.

Remedial Alternative 3A

- Soil Alternative 5a: Treatment of PAH and Arsenic Remediation Zone soils and combined phytoremediation/asphalt/building cap for marginal, and possibly, other remaining soils

- Groundwater Alternative 5: Infiltration reducing cap, treatment cells for harbor and lake, and monitored natural attenuation

Remedial Alternative 3B

- Soil Alternative 4b: Excavation and off-site disposal in a RCRA Subtitle C landfill for PAH and Arsenic Remediation Zone soils and combined phytoremediation/asphalt/building cap for marginal, and possibly, other remaining soils

- Groundwater Alternative 5: Infiltration reducing cap, treatment cells for harbor and lake, and monitored natural attenuation

In the above two alternatives (3A and 3B) each soil option includes excavation and either treatment or off-site disposal of PAH and Arsenic Remediation Zone soils. Both soil and groundwater alternatives include a phytoremediation infiltration reducing cap. The coverage would be selected to accomplish the objectives for both soil and groundwater. Combined caps (i.e., phyto/asphalt/building) are used for limiting exposure to soil, enhancing degradation of COCs in the soil, reducing COC mobility in the soil, and reducing the COC flux for groundwater. Under these alternatives, the capped areas can cover the entire impacted portions of the site. Treatment cells and monitored natural attenuation reduce contaminant mass to the lake and harbor .

Remedial Alternative 4

- Soil Alternative 5c: Treatment of PAH and Arsenic Remediation Zone soils and offsite disposal of marginal soil

- Groundwater Alternative 6: Aquifer Restoration

Removal of contaminated soil limits exposure to soil. Aquifer restoration requires pumping groundwater at 200 gpm with an onsite wastewater pretreatment unit and discharge to the POTW.

The above remedial alternatives are further evaluated in Section 5.

5.0 Detailed Analysis of Alternatives

5.1 Introduction

This section presents the detailed analysis of the retained Remedial Alternatives for the WCP site, including:

- Remedial Alternative 1: No Action
- Remedial Alternative 2: Containment
- Remedial Alternative 3: Removal
- Remedial Alternative 4: Aquifer Restoration

The components of these alternatives are shown in Table 4-10. These options provide a complete range of options for detailed analysis, as discussed below.

5.1.1 Alternatives Evaluation Process

Each Remedial Alternative is described in the following sections. Technical details of these alternatives may be found in Appendices 5-A and 5-B. The cost estimates are summarized in the descriptions of the remedial alternatives and are presented in detail in Appendix 5-C. The modeled effects of the groundwater remedies on groundwater flow and COC mass flux are presented in Appendix 5-D. An evaluation of monitored natural attenuation for Remedial Alternatives 2 and 3 is presented in Appendix 5-E. Following the alternative descriptions, the NCP criteria are used as a basis to evaluateadvantages and disadvantages of each alternative. The criteria used in this evaluation include (USEPA, 1988b):

1. Overall Protection of Human Health and the Environment
2. Compliance with ARARs
3. Long-Term Effectiveness and Performance
4. Reduction of Toxicity, Mobility, and Volume through Treatment
5. Short-Term Effectiveness
6. Implementability
7. Cost
8. State Acceptance
9. Community Acceptance

An evaluation of each alternative will be based on the first seven of the nine NCP criteria discussed in Section 5.1.1. The evaluation of state and community acceptance are conducted in the Record of Decision after the public comment period.

Table 5-1 provides a summary of the important characteristics of the nine evaluation criteria. The evaluation of each remedy based on these criteria is discussed in Section 5.3, and a comparative analysis of the remedies is in Section 6.0. Additional information concerning the regulatory meaning and purpose of these criteria can be found in USEPA, 1988b.

Federal and state action-specific ARARs for each alternative are presented in Table 5-2.

5.2 Description of Alternatives

5.2.1 Remedial Alternative 1: No Action

The no action alternative is the absence of any remedial actions. No action is considered in this evaluation as a baseline for comparison to all other potential remedial actions, as required by the NCP.

Under Remedial Alternative 1, no deliberate action is taken to address impacted soils and groundwater. However, contaminants will be naturally removed and/or attenuated over time. The baseline (no action) mass flux of contaminants from the groundwater to surface water over time is presented in Appendix 5-D and the modeled groundwater concentrations for representative beach and harbor transects are shown in Appendix 5-E. Table 5-2 does not include the No Action alternative as there would be no action-specific ARARs triggered by No Action.

5.2.2 Remedial Alternative 2: Containment

Remedial Alternative 2 consists of:

Vadose Zone Soil

- PAH Remediation Zone soil treatment by power plant co-burning or equivalent process
- Stabilization/solidification of Arsenic Remediation Zone soil
- Asphalt cap for Marginal Zone soil

- Land development restrictions to protect the integrity of the cap, the slurry wall (or groundwater containment structure), and the associated stormwater detention basin

Groundwater

- Containment system on the eastern portion of the site, consisting of a slurry wall system, and interior extraction/drainage units

- Treatment cells on beach and harbor with reinjection in cells. Ex-situ treatment includes removal of arsenic, phenols, organics, and ammonia.

- Monitored natural attenuation

- Infiltration reduction in areas capped with the asphalt cap, and the lined stormwater detention basin

- Institutional controls to prevent installation of potable wells

Variations of Remedial Alternative 2 are presented below. Action-specific ARARs for each of these variations are summarized in Table 5-2.

5.2.2.1 Remedial Alternative 2A

5.2.2.1.1 Soil Remedy

PAH and Arsenic Remediation Zones soils will be removed, as delineated on Figure 4-1. The PAH Remediation Zone soil will be processed and treated through power plant co-burning or equivalent process, as described in Appendix 5-A. The Arsenic Remediation Zone soil will be stabilized and placed on-site, as described in Appendix 5-A. Those portions of the Arsenic Remediation Zone soil suitable for incorporation in the PAH Remediation Zone soil remedy may be so incorporated. An asphalt cap will cover the slurry wall area which encompasses Marginal Zone soils. This cap will also limit the infiltration of groundwater into the slurry wall. The asphalt cap, however, requires construction of a lined stormwater detention basin, in order to comply with stormwater discharge permitting requirements for large asphalt parking areas. The layout for Alternative 2A is shown in Figure 5-1.

Land development restrictions must be imposed to protect the integrity of the cap, the slurry wall, and the stormwater detention basin. No utilities or foundations should be constructed in the slurry wall area.

5.2.2.1.2 Groundwater Remedy

The slurry wall would be installed to a depth of approximately 30 feet deep and would be keyed into the till. Other containment technologies that would serve the same function as the slurry wall include the Brown & Root SoilSaw, sheetpile or Waterloo barrier. Final selection would be made during remedial design.

The slurry wall alignment is selected to encompass the highest arsenic, phenol, and ammonia concentrations within the site groundwater. The slurry wall could not be extended eastward to encompass the highest offsite groundwater concentrations, due to two main reasons: (1) intervening utilities would compromise the wall, and (2) the natural beach dunes area would not accommodate a sustainable wall/cap system.

Water levels within the slurry wall will be maintained at or below the surrounding groundwater elevation. Excess water within the slurry wall and cap will be collected, treated to remove arsenic, organics, phenol, and ammonia and reinjected outside of the slurry wall. The water quality of the shallow portion of the sand aquifer within the slurry wall containment is expected to degrade because of potential mixing with the deep portion of the sand aquifer and the loss of aerobic biodegradation as an attenuation mechanism in the shallow groundwater.

The slurry wall and cap system may reduce the mass flux of contaminants to the harbor up to 50 percent, as shown in Appendix 5-D. The reduction in flux is as much a result of capping as it is of the slurry wall containment. Capping of much of the vacant land at the site is included in both Alternatives 2 and 3, but the Alternative 2 cap constricts potential future land use.

Groundwater treatment cells will be placed within the high-arsenic concentration area on the beach and the high-arsenic concentration near the south side of Slip No. 4 on the site as shown in Figures 5-1 and 5-2. The selection of these areas is presented in Appendix 4-B. This groundwater remedy may reduce the mass flux of contaminants to the lake by 50 to 80 percent, as shown in Appendix 5-D.

The treatment cells consist of a series of low-flow groundwater extraction and reinjection wells. Each treatment cell would have dimensions of approximately 100 by 200 feet, extracting at a rate of

15 gpm. Four cells would operate simultaneously, yielding a total flow of 60 gpm. At each treatment zone, the cell will be operated to extract, treat, and reinject a minimum of two pore volumes which should be accomplished in a 6- to 12-month period. Extraction of two pore volumes was selected based on the extraction effectiveness analysis discussed in Appendix 5-B. After the cell operation at one location is complete, the wells are sealed and abandoned, while the cell is moved to a new location to repeat the process.

A central treatment system would be used to treat the groundwater extracted at the cells. The ex-situ treatment system would be a complex four-stage system designed to remove arsenic, phenols, organics and ammonia. The combination of ex-situ treatment and reinjection will promote the natural degradation of the remaining organic contaminants in situ. The treatment cell concept is explained in more detail in Appendix 5-B. The effectiveness of the treatment cells will be demonstrated with a pilot test.

The installation of the asphalt cap and the stormwater detention basin will minimize or eliminate the infiltration rate through the soil, thereby reducing the groundwater hydraulic flux across the site and the associated contaminant flux to the surrounding water bodies. The reduced contaminant flux plus the removal of highly impacted groundwater will enhance natural attenuation of groundwater COCs outside the containment. This process will be monitored for a reasonable period of time following completion of remedial action. The purpose of the monitoring is to reaffirm the occurrence of natural attenuation. The scope, frequency, and duration of groundwater sampling to monitor natural attenuation will be determined during the design phase.

Institutional controls will also be implemented to prevent the placement of potable water supply wells where site groundwater exceeds drinking water standards. For this purpose, city ordinances and/or deed restrictions will be considered.

The total present worth estimated cost of Remedial Alternative 2A ranges from $38,900,000 (representative cost) to $50,300,000 (high cost). The representative cost estimate is summarized in Table 5-3. The high cost includes remediation of a higher volume of vadose zone soil and operation of treatment cells for 10 years instead of 5 years for the representative cost. A detailed cost estimate and assumptions are presented in Appendix 5-C. An evaluation of the NCP criteria is presented in Section 5.3.

5.2.2.2 Remedial Alternative 2B

Remedial Alternatives 2A and 2B are identical with the exception of the treatment process of the PAH and Arsenic Remediation Zone soil. Under this latter alternative, impacted soils from Remediation Zones will be removed and disposed at an off-site landfill. For cost estimation purposes, RCRA Subtitle C landfill disposal costs have been assumed. The PAH-impacted soil can be disposed of after some on-site processing, while the arsenic-impacted soil will be stabilized at the landfill facility prior to disposal. Disposal alternatives are described in Appendix 5-A. The total present worth estimated cost of Remedial Alternative 2B ranges from $37,800,000 (representative cost) to $50,400,000 (high cost). The representative cost estimate is summarized in Table 5-4. The high cost includes remediation of a higher volume of vadose zone soil and operation of treatment cells for 10 years instead of 5 years for the representative cost. A detailed cost estimate and assumptions are presented in Appendix 5-C. An evaluation of the NCP criteria is presented in Section 5.3.

5.2.2.3 Remedial Alternative 2C

Remedial Alternatives 2A and 2C are identical with the exception of the treatment process of the PAH and Arsenic Remediation Zone soil. Under this latter alternative, impacted soils from Remediation Zones will be removed and placed in an on-site vault designed consistent with requirements for a RCRA Subtitle C landfill. The design and construction of the on-site vault would be consistent with federal and state ARARs for construction of hazardous waste landfills. The conceptual design of the vault is described in Appendix 5-A.

The total present worth estimated cost of Remedial Alternative 2C ranges from $37,200,000 (representative cost) to $44,400,000 (high cost). The representative cost is summarized in Table 5-5. The high cost estimate scenario was discussed in the previous paragraphs. A detailed cost estimate and assumptions are presented in Appendix 5-C. An evaluation of the NCP criteria is presented in Section 5-3.

5.2.3 Remedial Alternative 3: Removal

Remedial Alternative 3 consists of:

Vadose Zone Soil

- PAH Remediation Zone soil treatment by power plant co-burning or equivalent process

- Stabilization/solidification of Arsenic Remediation Zone soil

- Phytoremediation cap for Marginal Zone soil, and the backfilled excavation areas

- Development of institutional controls and a post-remedy soil management plan

Groundwater

- Treatment cells on beach and harbor with reinjection in cells. Ex-situ treatment includes removal of arsenic, phenols, organics, and ammonia.

- Monitored natural attenuation

- Infiltration reduction through combined phytoremediation/asphalt/building cap

- Institutional controls to prevent installation of potable wells

Variations on Remedial Alternative 3 are presented below. Action-specific ARARs for Alternatives 3A and 3B are summarized in Table 5-2.

5.2.3.1 Remedial Alternative 3A

5.2.3.1.1 Soil Remedy

PAH and Arsenic Remediation Zone soil will be removed and treated, as discussed in Remedial Alternative 2A. Under Remedial Alternative 3A, the infiltration reducing cap will consist of a phytoremediation cap. Such caps have been applied for the remediation of PAH compounds. The phytoremediation cap minimizes infiltration through vadose zone, reduces groundwater flux to the harbor, and eliminates future direct exposures. The cap is sized to cover not only the Remediation and Marginal Zones, but also other parts of the site. Such an extensive cap provides protection that surpasses previously defined site remedial action objectives. The layout for Alternative 3A is shown in Figure 5-4.

The phytoremediation cap can be converted to other forms of infiltration-reducing covers, such as pavement and buildings. To accommodate such development, institutional controls and a post-remedy soil management plan will be developed to provide guidelines for implementation of various intrusive development activities. These controls will include site-specific protective procedures for construction of utility lines, buildings, and paved surfaces, as well as boat slips.

5.2.3.1.2 Groundwater Remedy

The cap system will reduce the mass flux of contaminants to the harbor up to 70 percent as shown in Appendix 5-D. Further, groundwater treatment cells similar to Remedial Alternative 2 will be placed within the high arsenic concentration area on the beach and on the south side of Slip No. 4 on the site as shown on Figures 5-2 and 5-4. This groundwater remedy is conservatively estimated to reduce the mass flux of contaminants to the lake by 40 to 80 percent, as shown in Appendix 5-D.

The ex-situ treatment system would be a robust two-stage system designed to remove arsenic, phenols, organics and ammonia. Ammonia removal and treatment system effectiveness will be determined after pilot testing of the cells. Potential ammonia removal scenarios are discussed in Appendix 5-B. The combination of ex-situ treatment and reinjection of possibly nitrate-rich water will promote the natural degradation of the remaining organic contaminants in situ. The treatment cell concept is explained in more detail in Appendix 5-B.

The contaminant flux reduction plus the removal of highly impacted groundwater will enhance natural attenuation of groundwater COCs. Natural attenuation will occur throughout the site as described in Appendix 5-E. The natural attenuation operates from the upper fringe of the concentrated COC zone at the base of the aquifer, progressively advancing downward until discharge of the COCs is practically eliminated. This process will be monitored for a reasonable period of time following completion of remedial action. The purpose of the monitoring is to reaffirm the occurrence of natural attenuation. The scope, frequency, and duration of groundwater sampling to monitor natural attenuation will be determined during the design phase.

Institutional controls will also be implemented to prevent the placement of potable water supply wells where site groundwater exceeds drinking water standards. For this purpose, city ordinances and/or deed restrictions will be considered.

The total present worth estimated cost of Remedial Alternative 3A ranges from $25,000,000 (representative cost) to $37,200,000 (high cost). The representative cost is summarized in Table 5-6. The high cost includes remediation of a higher volume of vadose zone soil and operation of treatment cells for 10 years instead of the 5 years for the representative cost. A detailed cost estimate and assumptions are presented in Appendix 5-C. An evaluation of NCP criteria is presented in Section 5.3.

5.2.3.2 Remedial Alternative 3B

Remedial Alternatives 3A and 3B are identical with the exception of the treatment of the PAH and Arsenic Remediation Zone soil. Under this latter alternative, impacted soils from Remediation Zones will be removed and disposed at an off-site landfill. For cost estimation purposes, RCRA Subtitle C landfill rates have been assumed. The PAH-impacted soil can be disposed of after some on-site processing, while the arsenic-impacted soil will be stabilized at the landfill facility prior to disposal. Disposal alternatives are described in Appendix 5-A. The total present worth estimated cost of Remedial Alternative 3B ranges from $23,900,000 (representative cost) to $37,000,000 (high cost). The representative cost is summarized in Table 5-7. The high cost scenario was discussed above. A detailed cost estimate and assumptions are presented in Appendix 5-C. An evaluation of NCP criteria is presented in Section 5.3.

5.2.4 Remedial Alternative 4: Aquifer Restoration

Remedial Alternative 4 consists of:

Vadose Zone Soil

- Excavation of PAH Remediation Zone soil and treatment by power plant co-burning or equivalent process

- Stabilization/solidification of Arsenic Remediation Zone soil

- Disposal at a RCRA Subtitle C or D landfill for marginal zone soil

Groundwater

- Groundwater extraction at 200 gpm from wells located along the hydraulic divide. Ex-situ treatment includes the removal of arsenic, phenols, organics, ammonia, and cyanide prior to discharge to NSSD.

- The groundwater remediation includes aquifer restoration to Class I and MCL groundwater standards.

Action-specific ARARs for this remedial alternative are summarized in Table 5-2.

5.2.4.1 Soil Remedy

The soil remedy of Remedial Alternative 4 includes soil removal similar to the soil remedy under Alternative 3B, as discussed in Section 5.2.3.2. In addition, the Marginal Zone soils will be transported to an off-site RCRA Subtitle C or D landfill.

5.2.4.2 Groundwater Remedy

The distinguishing feature of Remedial Alternative 4 is a high-flow groundwater pump-and-treat system, which would be operated until the Class I and MCL groundwater standards are attained. This system requires an extensive central treatment system to treat the extracted groundwater at 200 gpm. The ex-situ treatment system would be designed to remove arsenic, phenols, organics, ammonia and cyanide. The treated water would be discharged to the NSSD. Groundwater modeling, to estimate the time to cleanup for this alternative, is outside the capabilities of the groundwater model, as discussed in Appendix 5-E. The considerations discussed in Appendix 5-E call into questions the technical practicability of achieving the goal of restoring the aquifer with an aggressive groundwater remedy. A discussion on the technical impracticability (TI) of this remedy is included in Appendix 5-F.

The total present worth estimated cost of Remedial Alternative 4 is expected to exceed $101,000,000 as summarized in Table 5-8. A detailed cost estimate and assumptions are presented in Appendix 5-C. An evaluation of NCP criteria is presented in Section 5.3.

5.3 Detailed Analysis of Alternatives

This section presents a detailed analysis of the retained Remedial Alternatives for the WCP site. An evaluation of each alternative will be based on the first seven of the nine NCP criteria discussed in Section 5.1.1. The evaluation of state and community acceptance are conducted in the Record of Decision after the public comment period.

5.3.1 Remedial Alternative 1: No Action

5.3.1.1 Overall Protection of Human Health and Environment

Alternative 1 is not protective of human health and the environment because of unacceptable soil exposure risks. Potential long-term migration of contaminants to the surface water may cause exceedences of surface water standards in the near shore for selected contaminants, but even in the most severe scenarios is not calculated to produce concentrations in excess of human health or aquatic life criteria.

5.3.1.2 Compliance with ARARs

The evaluation of the ability of the alternatives to comply with ARARs included a review of Federal and State chemical-specific, location-specific, and action-specific ARARs. Alternative 1 does not comply with the ARARs identified for groundwater. Alternative 1 may also cause violation of the Lake Michigan surface water quality standard for ammonia under low mixing lake conditions. Action-specific ARARs do not apply because no actions are taken in this alternative.

5.3.1.3 Long-Term Effectiveness and Permanence

Alternative 1 is non-protective and could prolong the recovery of the site. The long-term effectiveness of the no-action alternative is dependent on the extent to which humans and the environment are naturally insulated from contact with the contaminants in the soil and the groundwater. The source has not been removed and so the existing risk remains. Natural attenuation and weathering will decrease the concentrations in groundwater and soil over time. Estimates of the concentrations of arsenic, ammonia, and phenol along representative transects over time for this alternative are presented in Appendix 5-E.

5.3.1.4 Reduction of Toxicity, Mobility, and Volume through Treatment

Alternative 1 would rely exclusively on natural attenuation processes to reduce toxicity, mobility and volume. Reduction of toxicity, mobility and volume through active treatment would not be achieved.

5.3.1.5 Short-Term Effectiveness

Alternative 1 does not require short-term actions to be implemented on the site.

5.3.1.6 Implementability

No implementation is required for the no action alternative.

5.3.1.7 Cost

The no action alternative has no direct cost. Indirect costs, such as the potential effect on property values or increased property redevelopment costs, are not considered in this study.

5.3.1.8 State and Community Acceptance

The evaluation of state and community acceptance are conducted in the Record of Decision.

5.3.2 Remedial Alternative 2: Containment

5.3.2.1 Remedial Alternative 2A

Remedial Alternative 2A is described in Section 5.2.2.

5.3.2.1.1 Overall Protection of Human Health and Environment

Alternative 2A is protective of human health and the environment as long as the containment system remains intact. The remedy removes and treats the highly impacted soil and groundwater, uses capping and institutional controls to eliminate direct contact with impacted soil and uses an asphalt cap to limit contact with soil contaminants. The remedy uses treatment cells to improve the quality of groundwater and enhance natural attenuation of groundwater contaminants, while protecting the lake against groundwater discharges at unacceptable levels. The slurry wall contains a portion of the contaminated groundwater and reduces discharge of groundwater into the harbor. The long-term requirement to extract, treat, and discharge the contained groundwater could decrease the protection of human health. This is due to the additional exposures caused by the long-term operation and maintenance of the groundwater treatment system.

For excavation of soil, the risk-based targets developed in accordance with U.S. EPA guidance have been used. The process used to develop these targets is also in conformance with the Illinois EPA's TACO guidance. Alternative 2A meets these requirements with excavation and treatment of soil and placement of an asphalt cap. The cap protects against soil ingestion to $1x10^{6}$ level (RHE) and minimizes the migration of COCs to groundwater. As shown in Appendix 4-A, the soil removal is calculated to be more protective than even 10^{-4} excess cancer risk, using the stringent RME commercial/industrial exposure scenario.

5.3.2.1.2 Compliance with ARARs

Alternative 2A complies with the ARARs listed in Section 3. These ARARs are culminated in the site-specific RAOs. The components of Alternative 2A will meet the stated RAOs by providing protective excavations and caps. The groundwater removal component will yield removals that surpass nearly all lake/harbor protection criteria. A GMZ will govern groundwater quality requirements during remediation. The water quality within the containment system can be expected to deteriorate over time, due to the absence of aerobic recharge that promotes natural degradation of organics.

Chemical-Specific ARARs

For excavation of soil, the risk-based targets developed in accordance with U.S. EPA guidance have been used. The process used to develop these targets is also in conformance with the Illinois EPA's TACO guidance.

The contaminant mass loading from groundwater discharging to surface water will be significantly reduced under this remedy, enhancing the compliance with surface water federal and state ARARs. Conditions at the site make groundwater restoration technically impracticable. Institutional controls will prohibit the placement of wells for potable use.

Location-Specific ARARs

Portions of the dunes area of the beach may be classified as wetland; Clean Water Act section 404 administered by the Army Corps of Engineers and Executive Order 11990 Protection of Wetlands may be location-specific ARARs. Installation of equipment for extraction and reinjection of groundwater on the beach may be impacted by these requirements. The site is adjacent to the Waukegan Harbor; Section 10 of the Rivers and Harbors Act is a location-specific ARAR. Remediation activities will not obstruct navigable waters. This alternative will be in compliance with the consent decree for the Outboard Marine Corporation/Waukegan Harbor site.

Action-Specific ARARs

Alternative 2A will meet action-specific ARARs summarized in Table 5-2 for soil and groundwater remedies. Action-specific ARARs include regulations for the following actions: excavation, on-site soil processing and treatment, transportation, capping of the containment area, and groundwater extraction, treatment, and reinjection. Air monitoring will be conducted during the excavation of contaminated soil for compliance with OSHA requirements.

Other Criteria and Guidance

To-be-considered criteria and guidance include the CERCLA guidance document "Land Use in the CERCLA Remedy Selection Process," Safe Drinking Water Act Secondary MCLs, Office of Drinking Water (drinking water health advisories), and Guidance for Evaluating the Technical Impracticability of Ground Water Restoration. The conclusion of application of the CERCLA land use guidance is that future land use at the site is non-residential. The achievement of groundwater standards is technically impracticable, and the groundwater ingestion pathway will be eliminated through institutional controls.

5.3.2.1.3 Long-Term Effectiveness and Permanence

The effectiveness and permanence of Alternative 2A rely upon the short-term simultaneous removal of source materials in both soil and groundwater. The short-term cell-based removal provides adequate time for detection of failure, diagnosis of the problem, and correction with the treatment cells or modification of the groundwater treatment process prior to any potential adverse impact to surrounding water bodies. The cell locations can also be modified in response to monitoring data. Long-term effectiveness and permanence are shown in the groundwater mass flux curves (Figures 5-6 through 5-8 for arsenic). Phenols and ammonia mass flux are shown in Appendix 5-D. Natural attenuation will enhance the long-term effectiveness of the groundwater remedy outside the containment, as explained in Appendix 5-E.

Alternative 2A constricts potential future site development. The integrity of the groundwater containment area cap must be assured, and a stormwater retention pond is required for management of surface water runoff from the large impervious area of the cap. The effectiveness of the remedy will be ensured by standard institutional controls that are fully compatible with the expected land use at the WCP site.

An asphalt cap reduces residual risk by providing adequate and reliable controls for direct contact with soil and migration of contaminants from soil to groundwater. Institutional controls for soil will assure the future use of the property is compatible with the remedy. Groundwater treatment combined with a cap and institutional controls provides an adequate and reliable control for direct contact with groundwater and migration to surface water. The groundwater containment area requires regular monitoring and perpetual low-flow extraction to assure its continued function. Periodic review may be required to ensure adequate protection of human health and the environment is maintained by the cap and groundwater containment.

5.3.2.1.4 Reduction of Toxicity, Mobility, and Volume through Treatment

Alternative 2A effectively reduces contaminant toxicity, mobility, and volume through treatment by the following actions:

- Remove and treat highly impacted soil
- Stabilize/solidify arsenic-impacted soil
- Remove and treat highly impacted groundwater
- Monitored natural attenuation following groundwater treatment

The above improvements will provide further protection of human health and the environment.

The PAH Remediation Zone soil will be removed and treated off-site, which will reduce the toxicity, mobility, and the volume of contaminated soil. Approximately 90 percent of the mass of PAHs will be removed and treated. The Arsenic Remediation Zone soil will be removed and treated by stabilization/solidification, reducing the toxicity and mobility of COCs at the site. Approximately 60 percent of the mass of arsenic on-site will be treated. The treated Arsenic Remediation Zone soil residuals will remain on site and the volume is expected to increase because of the addition of reagents.

The treatment of the groundwater reduces the toxicity, mobility, and volume of groundwater contamination and minimizes the migration of contaminants from groundwater to surface water. Two pore volumes removed from each treatment cell is calculated to achieve 85 percent removal for arsenic, 85 percent removal for ammonia and 35 percent removal for phenol in the treatment cells, although practical considerations may limit the attainable removal to 70 percent, as explained in Appendix 5-B. A minor amount of the groundwater remaining within the slurry wall will be treated over time.

The following table shows the percent mass removed through treatment cells for site groundwater in Alternative 2 (it is essentially identical for Alternatives 2A, 2B, and 2C). The percentages are shown to two significant figures, with the second figure rounded to the nearest five.

Alternative 2
Percent Mass Removed from Groundwater Through Treatment

	Discharge to Harbor	Discharge to Breakwater Area	Discharge to Lake Michigan	Total Site
Contaminant	**Treatment Cells**	**Treatment Cells**	**Treatment Cells**	**Treatment Cells**
Arsenic	7	50	65	45
Phenol	0.5	20	25	15
Ammonia	7	20	50	25

In addition to the mass removal through treatment cell action, it is anticipated that natural attenuation will progressively remove residual contamination in both the treated areas and the untreated areas outside the containment.

5.3.2.1.5 *Short-Term Effectiveness*

Alternative 2A includes short-term removal, processing, off-site shipment and treatment of PAH soil, and stabilization/solidification of arsenic-contaminated soil, installation of a cap and containment wall, and groundwater removal and treatment. The short-term effectiveness of these processes can be further enhanced through a number of measures such as: use of visual and predefined excavation criteria; pre-excavation confirmatory sampling; predefined cell extraction termination criteria; and practical, yet protective, treatment criteria. The soil removal, capping, and containment wall installation are proven technologies that can be implemented effectively over a short period of time. The flexible, cell-based groundwater removal also is expected to attain its remedial goals at a much faster rate than stationary pump-and-treat systems. The containment wall will require long-term maintenance and monitoring. A groundwater extraction and treatment system will be required as long as the containment system is in place. No adverse impacts on the lake and harbor are anticipated during remedy construction.

Excavation of soil would temporarily increase the potential for exposure to materials in the soil via release of dust. Protection of remediation workers, other nearby workers, or visitors to the area may be required during implementation of the remedy to reduce the potential for exposure to contaminants via direct contact or inhalation of fugitive dust.

Installation of the cell-based system may temporarily affect the natural sand dunes and vegetation on the beach. Temporary restrictions on public use of the dunes area during installation of the cells may be required for physical (not chemical) safety considerations.

5.3.2.1.6 *Implementability*

Each component of Alternative 2A has been demonstrated as a proven technology at other sites. Relying on predefined rules, such as visual excavation criteria, pre-excavation confirmatory sampling, and cell termination criteria can further enhance implementability of the remedial components. Further enhancement also can be achieved during the remedial design phase.

Excavation and treatment of PAH soil by power plant co-burning is a proven technology and has been demonstrated to be effective for treating organic compounds. The effect of Phase IV land disposal restrictions on the operation of the Baldwin facility is a matter of current discussion between the power plant and the IEPA. Soil processing will be required prior to transportation. Implementability will be enhanced by defining "areas of contamination" in which the soil can be consolidated prior to generation as a waste, consistent with Phase IV land disposal restrictions as discussed in Appendix 4-E. Excavation and treatment of arsenic soil by stabilization/solidification is a proven technology and has been demonstrated to be effective for metals. A stabilization/solidification treatability study will be required during the design stage. The asphalt cap and containment wall (i.e., slurry wall) are proven technologies. The asphalt cap requires a stormwater detention basin which limits future site development. Long-term care and maintenance are easily implementable using standard equipment and procedures.

The short-term flexible cell-based removal provides adequate time for detection of failure, diagnosis of the problem, and correction with the treatment cells or modification of the groundwater treatment process prior to any potential adverse impact to surrounding water bodies. The cell locations can also be modified in response to monitoring data. Treatment of site groundwater contaminants includes proven technologies. A pilot test will be completed during the remedial design phase to optimize water treatment, extraction, and reinjection. Equipment and materials for these systems are readily available. Operation of the system will require trained treatment system operators. Long-term care and maintenance of the water treatment system is easily implementable using standard equipment and procedures.

5.3.2.1.7 *Cost*

The cost of Alternative 2A is described in detail in Section 5.2. The present worth of the total cost has been estimated at $38.9 million assuming 5 percent interest for the anticipated duration of the remedial action.

5.3.2.1.8 *State and Community Acceptance*

The evaluation of state and community acceptance are conducted in thef Decision.

5.3.2.2 Remedial Alternative 2B

Remedial Alternative 2B is described in Section 5.2.2.

5.3.2.2.1 *Overall Protection of Human Health and Environment*

Alternative 2B is protective of human health and the environment as loie containment system remains intact. This alternative includes disposal of contaminated soil ff-site landfill. The potential risks associated with the excavated soil disposed at a landfill aressed by the engineering, monitoring, regulatory, and institutional controls associatethe treatment and disposal facilities. The remedy removes and treats the highly impacted gwater, uses capping and institutional controls to eliminate direct contact with impacted soil aes an asphalt cap to limit contact with soil contaminants. The remedy uses treatment cells toove the quality of groundwater and enhance natural attenuation of groundwater contaminawhile protecting the lake against groundwater discharges at unacceptable levels. The slurry tontains a portion of the contaminated groundwater and reduces discharge of groundwater into thrbor. The long-term requirement to extract, treat, and discharge the contained groundwater c decrease the protection of human health. This is due to the additional exposures caused by the lcerm operation and maintenance of the groundwater treatment system.

For excavation of soil, the risk-based targets developed in accordance witlS. EPA guidance ha been used. The process used to develop these targets is also in conformanwith the Illinois EPA TACO guidance. Alternative 2B meets these requirements with excavatioand treatment of so placement of an asphalt cap. The cap protects against soil ingestion to 1x? level (RHE) and minimizes the migration of COCs to groundwater. As shown in Appendix A, the soil removal calculated to be more protective than even 10^{-4} excess cancer risk, using thetringent RME commercial/industrial exposure scenario.

5.3.2.2.2 *Compliance with ARARs*

Alternative 2B complies with the ARARs listed in Section 3. These ARARs are ulminated in the site-specific RAOs. The components of Alternative 2B will meet the stated RAOs by providing protective excavations and caps. The groundwater removal component will yield removals that surpass nearly all lake/harbor protection criteria. A GMZ will govern groundwater quality requirements during remediation. The water quality within the containment system can be expected to deteriorate over time, due to the absence of aerobic recharge that promotes natural degradation of organics.

Chemical-Specific ARARs

For excavation of soil, the risk-based targets developed in accordance with U.S. EPA guidance have been used. The process used to develop these targets is also in conformance with the Illinois EPA's TACO guidance.

The contaminant mass loading from groundwater discharging to surface water will be significantly reduced under this remedy, enhancing the compliance with surface water federal and state ARARs. Conditions at the site make groundwater restoration technically impracticable. Institutional controls will prohibit the placement of wells for potable use.

Location-Specific ARARs

Portions of the dunes area of the beach may be classified as wetland; Clean Water Act section 404 administered by the Army Corps of Engineers and Executive Order 11990 Protection of Wetlands may be location-specific ARARs. Installation of equipment for extraction and reinjection of groundwater on the beach may be impacted by these requirements. The site is adjacent to the Waukegan Harbor; Section 10 of the Rivers and Harbors Act is a location-specific ARAR. Remediation activities will not obstruct navigable waters. This alternative will be in compliance with the consent decree for the Outboard Marine Corporation/Waukegan Harbor site.

Action-Specific ARARs

Alternative 2B will meet action-specific ARARs summarized in Table 5-2 for soil and groundwater remedies. Action-specific ARARs include regulations for the following actions: excavation, on-site soil processing, transportation, disposal of soil in a landfill, capping of the containment area, and groundwater extraction, treatment, and reinjection. Air monitoring will be conducted during the excavation of contaminated soil for compliance with OSHA requirements.

Other Criteria and Guidance

To-be-considered criteria and guidance include the CERCLA guidance document "Land Use in the CERCLA Remedy Selection Process," Safe Drinking Water Act Secondary MCLs, Office of Drinking Water (drinking water health advisories), and Guidance for Evaluating the Technical Impracticability of Ground Water Restoration. The conclusion of application of the CERCLA land use guidance is that future land use at the site is non-residential. The achievement of Class I or II groundwater standards is technically impracticable, and the groundwater ingestion pathway will be eliminated through institutional controls.

5.3.2.2.3 Long-Term Effectiveness and Permanence

The effectiveness and permanence of Alternative 2B rely upon the short-term simultaneous removal of source materials in both soil and groundwater. The short-term cell-based removal provides adequate time for detection of failure, diagnosis of the problem, and correction with the treatment cells or modification of the groundwater treatment process prior to any potential adverse impact to surrounding water bodies. The cell locations can also be modified in response to monitoring data. Long-term effectiveness and permanence are shown in the groundwater mass flux curves (Figures 5-6 through 5-8 for arsenic). Phenols and ammonia mass flux are shown in Appendix 5-D. Natural attenuation will enhance the long-term effectiveness of the groundwater remedy outside the containment, as explained in Appendix 5-E.

Alternative 2B constricts potential future site development. The integrity of the groundwater containment area cap must be assured, and a stormwater retention pond is required for management of surface water runoff from the large impervious area of the cap. The effectiveness of the remedy will be ensured by standard institutional controls that are fully compatible with the expected land use at the WCP site.

An asphalt cap reduces residual risk by providing adequate and reliable controls for direct contact with soil and migration of contaminants from soil to groundwater. Institutional controls for soil will assure the future use of the property is compatible with the remedy. Groundwater treatment combined with a cap and institutional controls provides an adequate and reliable control for direct contact with groundwater and migration to surface water. The groundwater containment area requires regular monitoring and perpetual low-flow extraction to assure its continued function. Periodic review may be required to ensure adequate protection of human health and the environment is maintained by the cap and groundwater containment.

5.3.2.2.4 Reduction of Toxicity, Mobility, and Volume through Treatment

Alternative 2B effectively reduces contaminant toxicity, mobility, and volume through treatment by the following actions:

- Remove and treat highly impacted groundwater
- Monitored natural attenuation following groundwater treatment

The above improvements will provide further protection of human health and the environment.

The treatment of the groundwater reduces the toxicity, mobility, and volume of groundwater contamination and minimizes the migration of contaminants from groundwater to surface water. Two pore volumes removed from each treatment cell is calculated to achieve 85 percent removal for arsenic, 85 percent removal for ammonia and 35 percent removal for phenol in the treatment cells, although practical considerations may limit the attainable removal to 70 percent, as explained in Appendix 5-B. A minor amount of the groundwater remaining within the slurry wall will be treated over time.

The following table shows the percent mass removed through treatment cells for site groundwater in Alternative 2 (it is essentially identical for Alternatives 2A, 2B, and 2C). The percentages are shown to two significant figures, with the second figure rounded to the nearest five.

Alternative 2
Percent Mass Removed from Groundwater Through Treatment

	Discharge to Harbor	Discharge to Breakwater Area	Discharge to Lake Michigan	Total Site
Contaminant	Treatment Cells	Treatment Cells	Treatment Cells	Treatment Cells
Arsenic	7	50	65	45
Phenol	0.5	20	25	15
Ammonia	7	20	50	25

In addition to the mass removal through treatment cell action, it is anticipated that natural attenuation will progressively remove residual contamination in both the treated areas and the untreated areas outside the containment.

5.3.2.2.5 Short-Term Effectiveness

Alternative 2B includes short-term removal, processing, off-site shipment and disposal of PAH and arsenic soil, and installation of a cap and containment wall, and groundwater removal and treatment. The short-term effectiveness of these processes can be further enhanced through a number of measures such as: use of visual and predefined excavation criteria; pre-excavation confirmatory sampling; predefined cell extraction termination criteria; and practical, yet protective, treatment criteria. The soil removal, capping, and containment wall installation are proven technologies that can be implemented effectively over a short period of time. The flexible, cell-based groundwater removal also is expected to attain its remedial goals at a much faster rate than stationary pump-and-treat systems. The containment wall will require long-term maintenance and monitoring. A groundwater extraction and treatment system will be required as long as the containment system is in place. No adverse impacts on the lake and harbor are anticipated during remedy construction.

Excavation of soil would temporarily increase the potential for exposure to materials in the soil via release of dust. Protection of remediation workers, other nearby workers, or visitors to the area may be required during implementation of the remedy to reduce the potential for exposure to contaminants via direct contact or inhalation of fugitive dust.

Installation of the cell-based system may temporarily affect the natural sand dunes and vegetation on the beach. Temporary restrictions on public use of the dunes area during installation of the cells may be required for physical (not chemical) safety considerations.

5.3.2.2.6 Implementability

Each component of Alternative 2B has been demonstrated as a proven technology at other sites. Relying on predefined rules, such as visual excavation criteria, pre-excavation confirmatory sampling, and cell termination criteria can further enhance implementability of the remedial components. Further enhancement also can be achieved during the remedial design phase.

Excavation and disposal of PAH and arsenic soil is a proven technology. Availability of landfill capacity and acceptance of soil (or pretreatment requirements) at a landfill under Phase IV land disposal restrictions will need to be determined prior to disposal. Soil processing may be required prior to transportation. The asphalt cap and containment wall (i.e., slurry wall) are proven technologies. The asphalt cap requires a stormwater detention basin which limits future site development. Long-term care and maintenance are easily implementable using standard equipment and procedures.

The short-term flexible cell-based removal provides adequate time for detection of failure, diagnosis of the problem, and correction with the treatment cells or modification of the groundwater treatment process prior to any potential adverse impact to surrounding water bodies. The cell locations can also be modified in response to monitoring data. Treatment of site groundwater contaminants includes proven technologies. A pilot test will be completed during the remedial design phase to optimize water treatment, extraction, and reinjection. Equipment and materials for these systems are readily available. Operation of the system will require trained treatment system operators. Long-term care and maintenance of the water treatment system is easily implementable using standard equipment and procedures.

5.3.2.2.7 Cost

The cost of Alternative 2B is described in detail in Section 5.2. The present worth of the total cost has been estimated at $37.8 million assuming 5 percent interest for the anticipated duration of the remedial action.

5.3.2.2.8 State and Community Acceptance

The evaluation of state and community acceptance are conducted in the Record of Decision.

5.3.2.3 Remedial Alternative 2C

Remedial Alternative 2C is described in Section 5.2.2.

5.3.2.3.1 Overall Protection of Human Health and Environment

Alternative 2C is protective of human health and the environment as long as the containment system remains intact. This alternative includes disposal of contaminated soil at an on-site containment unit. Disposal in a containment unit is protective of human health and the environment. The potential risks associated with the excavated soil disposed of on-site are addressed by the engineering, monitoring, regulatory, and institutional controls associated with the on-site containment unit. The remedy removes and treats the highly impacted groundwater, uses capping and institutional controls to eliminate direct contact with impacted soil and uses an asphalt cap to limit contact with soil contaminants. The remedy uses treatment cells to improve the quality of groundwater and enhance natural attenuation of groundwater contaminants, while protecting the lake against groundwater discharges at unacceptable levels. The slurry wall contains a portion of the contaminated groundwater and reduces discharge of groundwater into the harbor. The long-term requirement to extract, treat, and discharge the contained groundwater could decrease the protection of human health. This is due to the additional exposures caused by the long-term operation and maintenance of the groundwater treatment system.

For excavation of soil, the risk-based targets developed in accordance with U.S. EPA guidance have been used. The process used to develop these targets is also in conformance with the Illinois EPA's TACO guidance. Alternative 2C meets these requirements with excavation and treatment of soil and placement of an asphalt cap. The cap protects against soil ingestion to $1x10^{6}$ level (RHE) and minimizes the migration of COCs to groundwater. As shown in Appendix 4-A, the soil removal is calculated to be more protective than even 10^{-4} excess cancer risk, using the stringent RME commercial/industrial exposure scenario.

5.3.2.3.2 Compliance with ARARs

Alternative 2C complies with the ARARs listed in Section 3. These ARARs are culminated in the site-specific RAOs. The components of Alternative 2C will meet the stated RAOs by providing protective excavations and caps. The groundwater removal component will yield removals that surpass nearly all lake/harbor protection criteria. A GMZ will govern groundwater quality requirements during remediation. The water quality within the containment system can be expected to deteriorate over time, due to the absence of aerobic recharge that promotes natural degradation of organics.

Chemical-Specific ARARs

For excavation of soil, the risk-based targets developed in accordance with U.S. EPA guidance have been used. The process used to develop these PRGs is also in conformance with the Illinois EPA's TACO guidance.

The contaminant mass loading from groundwater discharging to surface water will be significantly reduced under this remedy, enhancing the compliance with surface water federal and state ARARs. Conditions at the site make groundwater restoration technically impracticable. Institutional controls will prohibit the placement of wells for potable use.

Location-Specific ARARs

Portions of the dunes area of the beach may be classified as wetland; Clean Water Act section 404 administered by the Army Corps of Engineers and Executive Order 11990 Protection of Wetlands may be location-specific ARARs. Installation of equipment for extraction and reinjection of groundwater on the beach may be impacted by these requirements. The site is adjacent to the Waukegan Harbor; Section 10 of the Rivers and Harbors Act is a location-specific ARAR. Remediation activities will not obstruct navigable waters. This alternative will be in compliance with the consent decree for the Outboard Marine Corporation/Waukegan Harbor site.

Action-Specific ARARs

Alternative 2C will meet action-specific ARARs summarized in Table 5-2 for soil and groundwater remedies. Action-specific ARARs include regulations for the following actions: excavation, on-site soil processing, disposal of soil in an on-site containment unit, capping of the containment area, and groundwater extraction, treatment, and reinjection. Air monitoring will be conducted during the excavation of contaminated soil for compliance with OSHA requirements. There are various federal and state action-specific ARARs for design, siting, construction, monitoring, and reporting associated with placement of contaminated soil in an on-site containment unit.

Other Criteria and Guidance

To-be-considered criteria and guidance include the CERCLA guidance document "Land Use in the CERCLA Remedy Selection Process," Safe Drinking Water Act Secondary MCLs, Office of Drinking Water (drinking water health advisories), and Guidance for Evaluating the Technical Impracticability of Ground Water Restoration. The conclusion of application of the CERCLA land use guidance is that future land use at the site is non-residential. The achievement of groundwater standards is technically impracticable, and the groundwater ingestion pathway will be eliminated through institutional controls.

5.3.2.3.3 Long-Term Effectiveness and Permanence

The effectiveness and permanence of Alternative 2C rely upon on the short-term simultaneous removal of source materials in both soil and groundwater. The short-term cell-based removal provides adequate time for detection of failure, diagnosis of the problem, and correction with the treatment cells or modification of the groundwater treatment process prior to any potential adverse impact to surrounding water bodies. The cell locations can also be modified in response to monitoring data. Long-term effectiveness and permanence are shown in the groundwater mass flux curves (Figures 5-6 through 5-8 for arsenic). Phenols and ammonia mass flux are shown in Appendix 5-D. Natural attenuation will enhance the long-term effectiveness of the groundwater remedy outside the containment, as explained in Appendix 5-E.

Alternative 2C does not include soil treatment or off-site disposal; it includes disposal of soil in an on-site containment unit. The design and construction of a containment unit in accordance with state and federal requirements would assure that this alternative provides an acceptable long-term solution. Permanence of a containment unit is assured through long-term maintenance of the containment system and long-term administration of institutional controls. The presence of the on-site containment unit is a significant additional constraint on the future use of the site.

Alternative 2C constricts potential future site development. The integrity of the groundwater containment area cap must be assured, and a stormwater retention pond is required for management of surface water runoff from the large impervious area of the cap. The effectiveness of the remedy will be ensured by standard institutional controls that are fully compatible with the expected land use at the WCP site.

An asphalt cap reduces residual risk by providing adequate and reliable controls for direct contact with soil and migration of contaminants from soil to groundwater. Institutional controls for soil will assure the future use of the property is compatible with the remedy. Groundwater treatment combined with a cap and institutional controls provides an adequate and reliable control for direct contact with groundwater and migration to surface water. The groundwater containment area requires regular monitoring and perpetual low-flow extraction to assure its continued function. Periodic review may be required to ensure adequate protection of human health and the environment is maintained by the cap and groundwater containment.

5.3.2.3.4 Reduction of Toxicity, Mobility, and Volume through Treatment

Alternative 2C effectively reduces contaminant toxicity, mobility, and volume through treatment by the following actions:

- Remove and treat highly impacted groundwater
- Monitored natural attenuation following groundwater treatment

The above improvements will provide further protection of human health and the environment.

The treatment of the groundwater reduces the toxicity, mobility, and volume of groundwater contamination and minimizes the migration of contaminants from groundwater to surface water. Two pore volumes removed from each treatment cell is calculated to achieve 85 percent removal for arsenic, 85 percent removal for ammonia and 35 percent removal for phenol in the treatment cells, although practical considerations may limit the attainable removal to 70 percent, as explained in Appendix 5-B. A minor amount of the groundwater remaining within the slurry wall will be treated over time.

The following table shows the percent mass removed through treatment cells for site groundwater in Alternative 2 (it is essentially identical for Alternatives 2A, 2B, and 2C). The percentages are shown to two significant figures, with the second figure rounded to the nearest five.

Alternative 2
Percent Mass Removed from Groundwater Through Treatment

	Discharge to Harbor	Discharge to Breakwater Area	Discharge to Lake Michigan	Total Site
Contaminant	Treatment Cells	Treatment Cells	Treatment Cells	Treatment Cells
Arsenic	7	50	65	45
Phenol	0.5	20	25	15
Ammonia	7	20	50	25

In addition to the mass removal through treatment cell action, it is anticipated that natural attenuation will progressively remove residual contamination in both the treated areas and the untreated areas outside the containment.

5.3.2.3.5 Short-Term Effectiveness

Alternative 2C includes short-term removal, processing, on-site containment unit for PAH and arsenic soil, and installation of a cap and containment wall, and groundwater removal and treatment. The short-term effectiveness of these processes can be further enhanced through a number of measures such as: use of visual and predefined excavation criteria; pre-excavation confirmatory sampling; predefined cell extraction termination criteria; and practical, yet protective, treatment criteria. The soil removal, capping, and containment wall installation are proven technologies that can be implemented effectively over a short period of time. The flexible, cell-based groundwater removal also is expected to attain its remedial goals at a much faster rate than stationary pump-and-treat systems. The on-site soil containment unit and groundwater containment wall will require long-term maintenance and monitoring. A groundwater extraction and treatment system will be required as long as the containment system and containment unit is in place. No adverse impacts on the lake and harbor are anticipated during remedy construction.

Excavation of soil would temporarily increase the potential for exposure to materials in the soil via release of dust. Protection of remediation workers, other nearby workers, or visitors to the area may be required during implementation of the remedy to reduce the potential for exposure to contaminants via direct contact or inhalation of fugitive dust.

Installation of the cell-based system may temporarily affect the natural sand dunes and vegetation on the beach. Temporary restrictions on public use of the dunes area during installation of the cells may be required for physical (not chemical) safety considerations.

5.3.2.3.6 Implementability

Each component of Alternative 2C has been demonstrated as a proven technology at other sites. Relying on predefined rules, such as visual excavation criteria, pre-excavation confirmatory sampling, and cell termination criteria can further enhance implementability of the remedial components. Further enhancement also can be achieved during the remedial design phase.

Excavation and disposal of PAH and arsenic soil is a proven technology. Containment units have been previously constructed, operated and maintained at numerous other locations. Standard construction, operation, and maintenance procedures would be used to construct and maintain the containment unit. A containment unit can likely be completed within one construction season. Long-term care and maintenance for the containment unit is easily implementable using standard equipment and procedures. The asphalt cap and containment wall (i.e., slurry wall) are proven technologies. The asphalt cap requires a stormwater detention basin which limits future site development. Long-term care and maintenance are easily implementable using standard equipment and procedures.

The short-term flexible cell-based removal provides adequate time for detection of failure, diagnosis of the problem, and correction with the treatment cells or modification of the groundwater treatment process prior to any potential adverse impact to surrounding water bodies. The cell locations can also be modified in response to monitoring data. Treatment of site groundwater contaminants includes proven technologies. A pilot test will be completed during the remedial design phase to optimize water treatment, extraction, and reinjection. Equipment and materials for these systems are readily available. Operation of the system will require trained treatment system operators. Long-term care and maintenance of the water treatment system is easily implementable using standard equipment and procedures.

5.3.2.3.7 Cost

The cost of Alternative 2C is described in detail in Section 5.2. The present worth of the total cost has been estimated at $37.2 million assuming 5 percent interest for the anticipated duration of the remedial action.

5.3.2.3.8 State and Community Acceptance

The evaluation of state and community acceptance are conducted in the Record of Decision.

5.3.3 Remedial Alternative 3: Removal

5.3.3.1 Remedial Alternative 3A

Remedial Alternative 3A is described in Section 5.2.3.

5.3.3.1.1 Overall Protection of Human Health and Environment

Alternative 3A is protective of human health and the environment throughout its life span. The remedy removes and treats the highly impacted soil and groundwater, uses capping and institutional controls to eliminate direct contact with impacted soil and uses phyto-capping to enhance natural attenuation of soil contaminants. The remedy uses treatment cells to improve the quality of groundwater and enhance natural attenuation of groundwater contaminants, while protecting the harbor and the lake against groundwater discharges at unacceptable levels.

For excavation of soil, the risk-based targets developed in accordance with U.S. EPA guidance have been used. The process used to develop these targets is also in conformance with the Illinois EPA's TACO guidance. Alternative 3A meets these requirements for excavation and treatment of soil and placement of a phyto-cap. The cap protects against soil ingestion to $1x10^{-6}$ level (RHE) and minimizes the migration of COCs to the groundwater pathway. As shown in Appendix 4-A, the soil removal is calculated to be more protective than even 10^{-4} excess cancer risk, using the stringent RME commercial/industrial exposure scenario.

5.3.3.1.2 Compliance with ARARs

Alternative 3A complies with the ARARs listed in Section 3. These ARARs are culminated in the site-specific RAOs. The components of Alternative 3A will surpass the stated RAOs by providing protective excavations and caps. The groundwater removal component will yield removals that surpass nearly all lake/harbor protection criteria. A GMZ will govern groundwater quality requirements during remediation.

Chemical-Specific ARARs

For excavation of soil, the risk-based targets developed in accordance with U.S. EPA guidance have been used. The process used to develop these targets is also in conformance with the Illinois EPA's TACO guidance.

The containment mass loading from groundwater discharging to surface water will be significantly reduced under this remedy, enhancing compliance with surface water federal and state ARARs. Conditions at the site make groundwater restoration technically impracticable. Institutional controls will prohibit the placement of wells for potable use.

Location-Specific ARARs

Portions of the dunes area of the beach may be classified as wetland; Clean Water Act section 404 administered by the Army Corps of Engineers and Executive Order 11990 Protection of Wetlands may be location-specific ARARs. Installation of equipment for extraction and reinjection of groundwater on the beach may be impacted by these requirements. The site is adjacent to the Waukegan Harbor; Section 10 of the Rivers and Harbors Act is a location specific ARAR. Remediation activities will not obstruct navigable waters. This alternative will be in compliance with the consent decree for the Outboard Marine Corporation/Waukegan Harbor site.

Action-Specific ARARs

Alternative 3A will meet action-specific ARARs summarized in Table 5-2 for soil and groundwater remedies. Action-specific ARARs include regulations for the following actions: excavation, on-site soil processing and treatment, transportation, and groundwater extraction, treatment and reinjection. Air monitoring will be conducted during the excavation of contaminated soil for compliance with OSHA requirements.

Other Criteria and Guidance

To-be-considered criteria and guidance include the CERCLA guidance document "Land Use in the CERCLA Remedy Selection Process," Safe Drinking Water Act Secondary MCLs, Office of Drinking Water (drinking water health advisories), and Guidance for Evaluating the Technical Impracticability of Ground Water Restoration. The conclusion of application of the CERCLA land use guidance is that future land use at the site is non-residential. The achievement of Class I and Class II groundwater standards is technically impracticable and the groundwater ingestion pathway will be eliminated through institutional controls.

5.3.3.1.3 *Long-Term Effectiveness and Permanence*

The effectiveness and permanence of Alternative 3A rely upon the short-term simultaneous removal of source materials in both soil and groundwater, followed by long-term natural attenuation supported by phytoremediation. The short-term cell-based removal provides adequate time for detection of failure, diagnosis of the problem, and correction with the treatment cells or modification of the groundwater treatment process prior to any potential adverse impact to surrounding water bodies. The cell locations can also be modified in response to monitoring data. Long-term effectiveness and permanence are shown in the groundwater mass flux curves (Figures 5-6 through 5-8 for arsenic). Phenols and ammonia mass flux are shown in Appendix 5-D. Natural attenuation will continue to remediate the groundwater after completion of the cell treatment, as explained in Appendix 5-E.

Alternative 3A also maximizes potential future site use. The combination of targeted removals, institutional land use controls, post-remedy soil management plan, and the flexible groundwater extraction and treatment system components and highly efficient implementation schedule allows for maximum future site use. The effectiveness of the remedy will also be ensured by standard institutional controls that are fully compatible with the expected land use at the WCP site.

A phyto-cap reduces residual risk by providing adequate and reliable controls for direct contact with soil and migration of contaminants from soil to groundwater. Institutional controls for soil will assure the future use of the property is compatible with the remedy. Groundwater treatment combined with a cap and institutional controls provides an adequate and reliable control for direct contact with groundwater and migration to surface water. Groundwater monitoring and institutional controls on water use and land use will ensure adequate protection of human health and the environment is maintained.

5.3.3.1.4 *Reduction of Toxicity, Mobility, and Volume through Treatment*

Alternative 3A effectively reduces contaminant toxicity, mobility, and volume through treatment by the following actions:

- Remove and treat highly impacted soil
- Stabilize/solidify arsenic-impacted soil
- Remove and treat highly impacted groundwater
- Monitored natural attenuation following groundwater treatment
- Reduce organic compound mobility and reduce leachate movement with the phyto-cap

The above improvements will provide further protection of human health and the environment.

The PAH Remediation Zone soil will be removed and treated off-site, which will reduce the toxicity, mobility, and the volume of contaminated soil. Approximately 90 percent of the mass of PAHs will be removed and treated. The Arsenic Remediation Zone soil will be removed and treated by stabilization/solidification, reducing the toxicity and mobility of COCs at the site. Approximately 60 percent of the mass of arsenic on site will be treated. The treated Arsenic Remediation Zone soil residuals will remain on site and the volume is expected to increase because of the addition of reagents. The remaining mass of the PAHs and arsenic (in excess of the soil to groundwater pathway concentration) will be managed with the phyto-cap. The phyto-cap gradually will reduce the mobility of the remaining organic contaminants by binding/degradation processes enhanced by adding organic matter to the soil. Biological action in the phyto-cap root zone can degrade organics, which may reduce the toxicity and volume of residual organic compounds. The phyto-cap will minimize the net annual infiltration and migration of residual contaminants to groundwater.

The treatment of the groundwater reduces the toxicity, mobility, and volume of groundwater contamination and minimizes the migration of contaminants from groundwater to surface water. Two pore volumes removed from each treatment cell is calculated to achieve 85 percent removal for arsenic, 55 to 85 percent removal for ammonia and 35 to 40 percent removal for phenol in the treatment cells, although practical considerations may limit the attainable removal to 70 percent, as explained in Appendix 5-B.

The following table shows the percent mass removed through treatment for site groundwater in Alternative 3 (it is essentially identical for Alternatives 3A and 3B). The percentages are shown to two significant figures, with the second figure rounded to the nearest five.

Alternative 3
Percent Mass Removed from Groundwater Through Treatment

Contaminant	Discharge to Harbor	Discharge to Breakwater Area	Discharge to Lake Michigan	Total Site
	Treatment Cells	Treatment Cells	Treatment Cells	Treatment Cells
Arsenic	7	50	65	45
Phenol	2	20	25 to 30	15
Ammonia	4 to 7	10 to 20	30 to 50	15 to 25

In addition to the mass removal through treatment cell action, it is anticipated that natural attenuation will progressively remove residual contamination in both the treated and the untreated areas, as explained in Appendix 5-E.

5.3.3.1.5 Short-Term Effectiveness

Alternative 3A includes short-term removal, processing, off-site shipment and treatment of PAH soil, stabilization/solidification of arsenic-contaminated soil, and groundwater removal and treatment. The short-term effectiveness of these processes can be further enhanced through a number of measures such as: use of visual and predefined excavation criteria; pre-excavation confirmatory sampling; predefined cell extraction termination criteria; and practical, yet protective, treatment criteria. The soil removal is a proven technology that can be implemented effectively over a short period of time. The phyto-cap progressively increases in effectiveness at reducing infiltration for approximately 3 years, and remains at stable effectiveness thereafter. The flexible, cell-based groundwater removal also is expected to attain its remedial goals at a much faster rate than stationary pump-and-treat systems. It is anticipated that this remedy could be completed in 5 years. Under Alternative 3A, protection of the lake and the harbor will be maintained and enhanced throughout the remedial action.

Excavation of soil would temporarily increase the potential for exposure to materials in the soil via release of dust. Protection of remediation workers, other nearby workers, or visitors to the area may be required during implementation of the remedy to reduce the potential for exposure to contaminants via direct contact or inhalation of fugitive dust.

Installation of the cell-based system may temporarily affect the natural sand dunes and vegetation on the beach. Temporary restrictions on public use of the dunes area during installation of the cells may be required for physical (not chemical) safety considerations.

5.3.3.1.6 Implementability

Each component of Alternative 3A has been demonstrated as a proven technology at other sites. Relying on predefined rules, such as visual excavation criteria, pre-excavation confirmatory sampling, and cell termination criteria can further enhance implementability of the remedial components. Further enhancement also can be achieved during the remedial design phase.

Excavation and treatment of PAH soil by power plant co-burning is a proven technology and has been demonstrated to be effective for treating organic compounds. The effect of Phase IV land disposal restrictions on the operation of the Baldwin facility is a matter of current discussion between the power plant and the IEPA. Soil processing will be required prior to transportation. Implementability will be enhanced by defining "areas of contamination" in which the soil can be consolidated prior to generation as a waste, consistent with Phase IV land disposal restrictions as discussed in Appendix 4-E. Excavation and treatment of arsenic soil by stabilization/solidification is a proven technology and has been demonstrated to be effective for metals. A stabilization/solidification treatability study will be required during the design stage. Evapotranspiration, the mechanism by which the phyto-cap reduces net annual infiltration, is a fundamental hydrologic process. Phytoremediation for organic COC and metals remediation is an effective technology which has been applied at numerous sites. A phytoremediation cap can be changed to asphalt or buildings as future site development progresses.

The short-term flexible cell-based removal provides adequate time for detection of failure, diagnosis of the problem, and correction with the treatment cells or modification of the groundwater treatment process prior to any potential adverse impact to surrounding water bodies. The cell locations can also be modified in response to monitoring data. Treatment of site groundwater contaminants includes proven technologies. A pilot test will be completed during the remedial design phase to optimize water treatment, extraction, and reinjection. Equipment and materials for these systems are readily available. Operation of the system will require trained treatment system operators.

5.3.3.1.7 Cost

The cost of Alternative 3A is described in detail in Section 5.2. The present worth of the total cost has been estimated at $25.0 million assuming 5 percent interest for the anticipated duration of the remedial action.

5.3.3.1.8 State and Community Acceptance

The evaluation of state and community acceptance are conducted in the Record of Decision.

5.3.3.2 Remedial Alternative 3B

Remedial Alternative 3B is described in Section 5.2.3.

5.3.3.2.1 Overall Protection of Human Health and Environment

Alternative 3B is protective of human health and the environment throughout its life span. This alternative includes disposal of contaminated soil at an off-site landfill. Disposal in a landfill is protective of human health and the environment. The potential risks associated with the excavated soil disposed at a landfill are addressed by the engineering, monitoring, regulatory, and institutional controls associated with the treatment and disposal facilities. The remedy removes and treats the highly impacted groundwater, uses capping and institutional controls to eliminate direct contact with impacted soil and uses phyto-capping to enhance natural attenuation of soil contaminants. The remedy uses treatment cells to improve the quality of groundwater and enhance natural attenuation of groundwater contaminants, while protecting the harbor and the lake against groundwater discharges at unacceptable levels.

For excavation of soil, the risk-based targets developed in accordance with U.S. EPA guidance have been used. The process used to develop these targets is also in conformance with the Illinois EPA's TACO guidance. Alternative 3B meets these requirements for excavation and treatment of soil and placement of a phyto-cap. The cap protects against soil ingestion to $1x10^{-6}$ level (RHE) and minimizes the migration of COCs to the groundwater pathway. As shown in Appendix 4-A, the soil removal is calculated to be more protective than even 10^{-4} excess cancer risk, using the stringent RME commercial/industrial exposure scenario.

5.3.3.2.2 Compliance with ARARs

Alternative 3B complies with the ARARs listed in Section 3. These ARARs are culminated in the site-specific RAOs. The components of Alternative 3B will surpass the stated RAOs by providing protective excavations and caps. The groundwater removal component will yield removals that surpass nearly all lake/harbor protection criteria. A GMZ will govern groundwater quality requirements during remediation.

Chemical-Specific ARARs

For excavation of soil, the risk-based targets developed in accordance with U.S. EPA guidance have been used. The process used to develop these targets is also in conformance with the Illinois EPA's TACO guidance.

The containment mass loading from groundwater discharging to surface water will be significantly reduced under this remedy, enhancing compliance with surface water federal and state ARARs.

Conditions at the site make groundwater restoration technically impracticable. Institutional controls will prohibit the placement of wells for potable use.

Location-Specific ARARs

Portions of the dunes area of the beach may be classified as wetland; Clean Water Act section 404 administered by the Army Corps of Engineers and Executive Order 11990 Protection of Wetlands may be location-specific ARARs. Installation of equipment for extraction and reinjection of groundwater on the beach may be impacted by these requirements. The site is adjacent to the Waukegan Harbor; Section 10 of the Rivers and Harbors Act is a location specific ARAR. Remediation activities will not obstruct navigable waters. This alternative will be in compliance with the consent decree for the Outboard Marine Corporation/Waukegan Harbor site.

Action-Specific ARARs

Alternative 3B will meet action-specific ARARs summarized in Table 5-2 for soil and groundwater remedies. Action-specific ARARs include regulations for the following actions: excavation, on-site soil processing, transportation, off-site disposal of soil in a landfill, and groundwater extraction, treatment and reinjection. Air monitoring will be conducted during the excavation of contaminated soil for compliance with OSHA requirements.

Other Criteria and Guidance

To-be-considered criteria and guidance include the CERCLA guidance document "Land Use in the CERCLA Remedy Selection Process," Safe Drinking Water Act Secondary MCLs, Office of Drinking Water (drinking water health advisories), and Guidance for Evaluating the Technical Impracticability of Ground Water Restoration. The conclusion of application of the CERCLA land use guidance is that future land use at the site is non-residential. The achievement of groundwater standards is technically impracticable and the groundwater ingestion pathway will be eliminated through institutional controls.

5.3.3.2.3 Long-Term Effectiveness and Permanence

The effectiveness and permanence of Alternative 3B rely upon the short-term simultaneous removal of source materials in both soil and groundwater, followed by long-term natural attenuation supported by phytoremediation. The short-term cell-based removal provides adequate time for detection of failure, diagnosis of the problem, and correction with the treatment cells or modification of the groundwater treatment process prior to any potential adverse impact to surrounding water bodies. The cell locations can also be modified in response to monitoring data. Long-term effectiveness and permanence are shown in the groundwater mass flux curves (Figures 5-6 through 5-8 for arsenic). Phenols and ammonia mass flux are shown in Appendix 5-D. Natural attenuation will continue to remediate the groundwater after completion of the cell treatment, as explained in Appendix 5-E.

Alternative 3B also maximizes potential future site use. The combination of targeted removals, institutional land use controls, post-remedy soil management plan, and the flexible groundwater extraction and treatment system components and highly efficient implementation schedule allows for maximum future site use. The effectiveness of the remedy will also be ensured by standard institutional controls that are fully compatible with the expected land use at the WCP site.

A phyto-cap reduces residual risk by providing adequate and reliable controls for direct contact with soil and migration of contaminants from soil to groundwater. Institutional controls for soil will assure the future use of the property is compatible with the remedy. Groundwater treatment combined with a cap and institutional controls provides an adequate and reliable control for direct contact with groundwater and migration to surface water. Groundwater monitoring and institutional controls on water use and land use will ensure adequate protection of human health and the environment is maintained.

5.3.3.2.4 Reduction of Toxicity, Mobility, and Volume through Treatment

Alternative 3B effectively reduces contaminant toxicity, mobility, and volume through treatment by the following actions:

- Remove and treat highly impacted groundwater
- Monitored natural attenuation following groundwater treatment
- Reduce organic compound mobility and reduce leachate movement with the phyto-cap

The above improvements will provide further protection of human health and the environment.

The PAH and Arsenic Remediation Zone soil will be removed and disposed off-site. The remaining mass of the PAHs and arsenic (in excess of the soil to groundwater pathway concentration) will be managed with the phyto-cap. The phyto-cap gradually will reduce the mobility of the remaining organic contaminants by binding/degradation processes enhanced by adding organic matter to the soil. Biological action in the phyto-cap root zone can degrade organics, which may reduce the toxicity and volume of the residual organic compounds. The phyto-cap will minimize the net annual infiltration and migration of residual contaminants to groundwater.

The treatment of the groundwater reduces the toxicity, mobility, and volume of groundwater contamination and minimizes the migration of contaminants from groundwater to surface water. Two pore volumes removed from each treatment cell is calculated to achieve 85 percent removal for arsenic, 55 to 85 percent removal for ammonia and 35 to 40 percent removal for phenol in the treatment cells, although practical considerations may limit the attainable removal to 70 percent, as explained in Appendix 5-B.

The following table shows the percent mass removed through treatment for site groundwater in Alternative 3 (it is essentially identical for Alternatives 3A and 3B). The percentages are shown to two significant figures, with the second figure rounded to the nearest five.

Alternative 3
Percent Mass Removed from Groundwater Through Treatment

Contaminant	Discharge to Harbor	Discharge to Breakwater Area	Discharge to Lake Michigan	Total Site
	Treatment Cells	Treatment Cells	Treatment Cells	Treatment Cells
Arsenic	7	50	65	45
Phenol	2	20	25 to 30	15
Ammonia	4 to 7	10 to 20	30 to 50	15 to 25

In addition to the mass removal through treatment cell action, it is anticipated that natural attenuation will progressively remove residual contamination in both the treated and the untreated areas, as explained in Appendix 5-E.

5.3.3.2.5 Short-Term Effectiveness

Alternative 3B includes short-term removal, processing, off-site shipment and disposal of PAH and arsenic soil, and groundwater removal and treatment. The short-term effectiveness of these processes can be further enhanced through a number of measures such as: use of visual and predefined excavation criteria; pre-excavation confirmatory sampling; predefined cell extraction termination criteria; and practical, yet protective, treatment criteria. The soil removal is a proven technology that can be implemented effectively over a short period of time. The phyto-cap progressively increases in effectiveness at reducing infiltration for approximately 3 years, and remains at stable effectiveness thereafter. The flexible, cell-based groundwater removal also is expected to attain its remedial goals at a much faster rate than stationary pump-and-treat systems. It is anticipated that this remedy could be completed in 5 years. Under Alternative 3B, protection of the lake and the harbor will be maintained and enhanced throughout the remedial action.

Excavation of soil would temporarily increase the potential for exposure to materials in the soil via release of dust. Protection of remediation workers, other nearby workers, or visitors to the area may be required during implementation of the remedy to reduce the potential for exposure to contaminants via direct contact or inhalation of fugitive dust.

Installation of the cell-based system may temporarily affect the natural sand dunes and vegetation on the beach. Temporary restrictions on public use of the dunes area during installation of the cells may be required for physical (not chemical) safety considerations.

5.3.3.2.6 Implementability

Each component of Alternative 3B has been demonstrated as a proven technology at other sites. Relying on predefined rules, such as visual excavation criteria, pre-excavation confirmatory sampling, and cell termination criteria can further enhance implementability of the remedial components. Further enhancement also can be achieved during the remedial design phase.

Excavation and disposal of PAH and arsenic soil is a proven technology. Availability of landfill capacity and acceptance of soil (or pretreatment requirements) at a landfill under Phase IV land disposal restrictions will need to be determined prior to disposal. Soil processing may be required prior to transportation. Evapotranspiration, the mechanism by which the phyto-cap reduces net annual infiltration, is a fundamental hydrologic process. Phytoremediation for organic COC and metals remediation is an effective technology which has been applied at numerous sites.
A phytoremediation cap can be changed to asphalt or buildings as future site development progresses.

The short-term flexible cell-based removal provides adequate time for detection of failure, diagnosis of the problem, and correction with the treatment cells or modification of the groundwater treatment process prior to any potential adverse impact to surrounding water bodies. The cell locations can also be modified in response to monitoring data. Treatment of site groundwater contaminants includes proven technologies. A pilot test will be completed during the remedial design phase to optimize water treatment, extraction, and reinjection. Equipment and materials for these systems are readily available. Operation of the system will require trained treatment system operators.

5.3.3.2.7 Cost

The cost of Alternative 3B is described in detail in Section 5.2. The present worth of the total cost has been estimated at $23.9 million assuming 5 percent interest for the anticipated duration of the remedial action.

5.3.3.2.8 State and Community Acceptance

The evaluation of state and community acceptance are conducted in the Record of Decision.

5.3.4 Remedial Alternative 4: Aquifer Restoration

Remedial Alternative 4 is described in Section 5.2.4.

5.3.4.1 Overall Protection of Human Health and Environment

Alternative 4 is protective of human health and the environment throughout the active remedy period. The remedy removes and treats the highly impacted soil and attempts to remove and treat the groundwater. The remedy uses an active pump and treat system with discharge to the POTW to remediate the groundwater, while protecting the harbor and the lake against groundwater discharges at unacceptable levels. As discussed in Appendix 3-E, the objective of achieving groundwater quality standards is technically impracticable.

5.3.4.2 Compliance with ARARs

Alternative 4 does not comply with the ARARs listed in Section 3. It is technically impracticable to achieve Illinois Class I or MCL groundwater requirements.

Chemical-Specific ARARs

For excavation of soil, the risk-based targets developed in accordance with U.S. EPA guidance have been used. The process used to develop these targets is also in conformance with the Illinois EPA's TACO guidance. Alternative 4 meets these requirements for excavation and treatment of soil.

The contaminant mass loading from groundwater discharge to surface water will be significantly reduced under this remedy, enhancing compliance with surface water federal and state ARARs. Conditions at the site make groundwater restoration technically impracticable. A waiver would be required for Illinois Class I or MCL groundwater standards.

Location-Specific ARARs

Portions of the dunes area of the beach may be classified as wetland; Clean Water Act section 404 administered by the Army Corps of Engineers and Executive Order 11990 Protection of Wetlands may be location-specific ARARs. Installation of equipment for extraction of groundwater on the beach may be impacted by these requirements. The site is adjacent to the Waukegan Harbor; Section 10 of the Rivers and Harbors Act is a location specific ARAR. Remediation activities will not obstruct navigable waters. This alternative will be in compliance with the consent decree for the Outboard Marine Corporation/Waukegan Harbor site.

Action-Specific ARARs

Alternative 4 will meet action-specific ARARs summarized in Table 5-2 for soil and groundwater remedies. Action-specific ARARs include regulations for the following actions: excavation, on-site soil processing and treatment, transportation, wastewater extraction, treatment and discharge to the POTW. Air monitoring will be conducted during the excavation of contaminated soil for compliance with OSHA requirements.

Other Criteria and Guidance

To-be-considered criteria and guidance include the CERCLA guidance document "Land Use in the CERCLA Remedy Selection Process," Safe Drinking Water Act Secondary MCLs, Office of Drinking Water (drinking water health advisories), and Guidance for Evaluating the Technical Impracticability of Ground Water Restoration. The conclusion of application of the CERCLA land use guidance is that future land use at the site is non-residential. The achievement of groundwater standards is technically impracticable, so that institutional controls which were intended to be temporary to restrict potable use of groundwater during the remedial action, will have to be permanent.

5.3.4.3 Long-Term Effectiveness and Permanence

Alternative 4 cannot achieve long-term effectiveness and permanence because it is technically impracticable for groundwater.

The residual risk associated with soil outside the area designated for removal and treatment is eliminated by removing and landfilling the residual soil. This eliminates both direct contact and migration of contaminants from soil to groundwater. The residual risk for groundwater for existing and future users cannot be removed without the use of institutional controls. This remedy will be ongoing for decades.

5.3.4.4 Reduction of Toxicity, Mobility, and Volume through Treatment

Alternative 4 effectively reduces contaminant toxicity, mobility, and volume through treatment by the following actions:

- Remove and treat highly impacted soil
- Stabilize/solidify arsenic-impacted soil
- Remove and treat highly impacted groundwater

The above improvements will provide protection of human health and the environment.

The PAH Remediation Zone soil will be removed and treated off-site, which will reduce the toxicity, mobility, and the volume of contaminated soil. Approximately 90 percent of the mass of PAHs will be removed and treated. The Arsenic Remediation Zone soil will be removed and treated by stabilization/solidification, reducing the toxicity and mobility of COCs at the site. Approximately 60 percent of the mass of arsenic on-site will be treated. The treated Arsenic Remediation Zone soil residuals will be disposed of off-site. The remaining soils will be disposed of in a RCRA Subtitle C or D landfill.

The treatment of the groundwater reduces the toxicity, mobility, and volume of groundwater contamination and minimizes the migration of contaminants from groundwater to surface water. Conditions at the site make groundwater restoration technically impracticable.

The following table shows the percent mass that must be removed from the groundwater in order for Alternative 4 to meet Class I or II groundwater standards:

Alternative 4
Percent Mass That Must be Removed from Aquifer

Contaminant	Total Site	
	Class I	Class II
Arsenic	99.5	98.1
Phenol	99.99	99.99
Benzene	99.92	99.6

These mass removal requirements cannot be achieved, and serve to illustrate the impracticability of achieving Class I groundwater standards and MCLS, or even Class II standards. The calculation of the required removals is based on the average groundwater quality, and uses soil-water partition coefficients of 0.54 for phenol and 0.98 for benzene. No ammonia removal requirement is shown because there is no MCL or Illinois groundwater standard for ammonia.

5.3.4.5 Short-Term Effectiveness

Alternative 4 includes short-term removal, processing, off-site shipment and treatment of PAH soil, stabilization/solidification of contaminated soil, and groundwater removal and treatment. The short-term effectiveness of these processes can be further enhanced through a number of measures such as: use of visual and predefined excavation criteria; and pre-excavation confirmatory sampling. The soil removal is a proven technology, but the volume of soil to remove will increase the potential for dust generation and adverse short-term effects. The groundwater removal will require long-term maintenance and administration. It is anticipated that this remedy could last for more than several decades. Under Alternative 4, protection of the lake and the harbor will be maintained.

Excavation of soil would temporarily increase the potential for exposure to materials in the soil via release of dust. Protection of remediation workers, other nearby workers, or visitors to the area may be required during implementation of the remedy to reduce the potential for exposure to contaminants via direct contact or inhalation of fugitive dust.

Installation of the groundwater system may temporarily affect the natural sand dunes and vegetation on the beach. Issues related to installation and long-term maintenance of wells on a public beach will need to be addressed.

5.3.4.6 Implementability

The soil remedy components of Alternative 4 have been demonstrated as proven technologies at other sites. Relying on predefined rules, such as visual excavation criteria, and pre-excavation confirmatory sampling can further enhance implementability of the remedial components. Further enhancement also can be achieved during the remedial design phase.

Excavation and treatment of PAH soil by power plant co-burning is a proven technology and has been demonstrated to be effective for treating organic compounds. The effect of Phase IV land disposal restrictions on the operation of the Baldwin facility is a matter of discussion between the power plant and the EPA. Soil processing will be required prior to transportation. Implementability will be enhanced by defining "areas of contamination" in which the soil can be consolidated prior to generation as a waste, consistent with Phase IV land disposal restrictions as discussed in

Appendix 4-E. Excavation and treatment of arsenic soil by stabilization/solidification is a proven technology and has been demonstrated to be effective for metals. A stabilization/solidification treatability study will be required during the design stage. Disposal facility acceptance of Marginal Zone soils at a RCRA Subtitle C or D landfill will need to be addressed; however, landfill disposal is a proven technology.

The groundwater treatment technology has been well-demonstrated, but may not be able to sustain the pumping rates needed, and it is technically impracticable to achieve the stated objective of attaining Class I and MCL groundwater standards. The technical impracticability of achieving the groundwater standards is illustrated in Section 5.3.4.4 above and Appendix 5-F. Wastewater treatment of site groundwater contaminants includes proven technologies. A pilot test would be completed during the remedial design phase to optimize wastewater treatment and extraction. Equipment and materials are readily available. Operation of the system will require trained wastewater treatment operators. Acceptance of the pretreated water at the NSSD would be required.

5.3.4.7 Cost

The cost of Alternative 4 is described in detail in Section 5.2. The present worth of the total cost has been estimated at $101 million at 5 percent interest for a 30-year duration of the remedial action, although the groundwater remedial action must be expected to require a much longer duration.

5.3.4.8 State and Community Acceptance

The evaluation of state and community acceptance are conducted in the Record of Decision.

6.0 Comparative Analysis of Alternatives

6.1 NCP Criteria Evaluation

Detailed analysis of the seven NCP criteria on the four Remedial Alternatives is described in Section 5.3. The comparative analysis is presented below and summarized in Table 6-1.

6.1.1 Protection of Human Health and the Environment

The No Action alternative is not protective of human health and the environment for two reasons: (1) unacceptable soil exposure risks, and (2) potential long-term migration of contaminants to the surface water.

Remedial Alternatives 2, 3, and 4 are protective of human health and the environment throughout their life spans. These remedies would eliminate direct contact to contaminated soil and minimize the migration of contaminants from soil via groundwater to surface water. The protectiveness of these alternatives would be ensured through institutional controls to restrict on-site groundwater use.

The slurry wall in Remedial Alternative 2, however, does not increase the protection of human health and the environment. The long-term requirement to manage the contained groundwater through pumping and treatment could decrease the protection of human health. This is due to the additional exposures caused by the long-term operation and maintenance of the system. Remedial Alternative 4 is also technically impracticable, and thus, cannot be considered more protective of human health and the environment than the other alternatives.

6.1.2 Compliance with ARARs

As noted above, the No Action alternative does not meet ARARs due to unacceptable surface soil exposures. Remedial Alternatives 2 and 3meet ARARs, with active groundwater remedies, designed to protect the surface water. The technical impracticability of Remedial Alternative 4 may require the waiver of Class I and MCL groundwater standards ARARs.

6.1.3 Long-Term Effectiveness and Permanence

The No Action alternative is currently non-protective and could prolong the recovery of the site.

Remedial Alternatives 2, 3, and 4 aim at removing and capping PAH- and arsenic-impacted soils. Remedial Alternative 3, however, includes the added remedial benefits of an extended phytoremediation cap, which further enhance the long-term effectiveness and permanence of this remedy. Institutional controls in Remedial Alternative 3 also assure future, protective development of the site. These controls ensure the permanence of the appropriate long-term management of site activities.

Concerning groundwater remedies, Remedial Alternatives 2, 3, and 4 include contaminant removal and flux reduction. Given the technical impracticability of attaining Class I and MCL groundwater standards (Remedial Alternative 4), the remaining alternatives (2 and 3) provide equivalent long-term effectiveness and permanence as shown in the groundwater mass flux (Figures 5-6 through 5-8 for arsenic). Figures 5-6 through 5-8 summarize the mass flux comparison for Alternatives 2 and 3 for arsenic to Lake Michigan, the breakwater area and Waukegan Harbor. Phenols and ammonia mass flux comparison for Alternatives 2 and 3 are shown in Appendix 5-D.

In summary, Remedial Alternative 3 is a technically practicable remedy, with enhanced long-term effectiveness compared to Remedial Alternatives 1, 2 and 4. The advantages of Remedial Alternative 3 are due to: (1) a flexible, extended cap with phytoremediation capabilities, (2) a groundwater treatment system that can further enhance the in-situ biodegradation of contaminants, and (3) protective institutional controls and post-remedy soil management plan for soil.

6.1.4 Reduction of Toxicity, Mobility or Volume Through Treatment

The No Action alternative includes no treatment and would rely on unenhanced natural attenuation processes to reduce toxicity, mobility, and volume.

Remedial Alternatives 2, 3, and 4 would reduce contaminant toxicity, mobility, and/or volume through treatment to various degrees. Remedial Alternatives 2A, 3A and 4 include soil treatment components including power plant co-burning or equivalent process and stabilization of soil. Alternative 3A includes a phytoremediation cap to treat PAH Remediation Zone soil. Remedial Alternative 2 and 3 reduces the toxicity and volume of COCs in groundwater by treatment with cells. Remedial Alternative 4 reduces toxicity and volume of COCs in groundwater with a full pump and treatment system.

Remedial Alternative 3 offers continuous reduction in COCs in soil through treatment with the use of a phytoremediation cap. Although Alternative 4 offers significant reduction of COCs in groundwater as compared to other alternatives, this alternative is technically impracticable for various constituents. Alternative 3, when compared to other alternatives, provides beneficial reduction of COCs in groundwater through treatment and is cost-effective as discussed in following sections.

6.1.5 Short-Term Effectiveness

The No Action alternative does not require short-term actions to be implemented at the site. In contrast, Remedial Alternatives 2, 3, and 4 include excavation of contaminated soil. Remedial Alternatives 2 and 3 include capping of remaining soil. Soil removal and capping are proven technologies that can be implemented over a short period of time.

Remedial Alternative 4, however, requires excavation of about 100,000 cubic yards of contaminated soil. This alternative poses significantly more potential for short-term risks than Remedial Alternatives 2 and 3 which includes excavation of about 10,000 cubic yards of soil. In the short term, a cap provides an additional layer of protection for the site to prohibit direct contact, reduce infiltration to groundwater, reduce migration of contaminants from soil to groundwater and groundwater to surface water.

Remedial Alternative 3 is more effective in the short-term for groundwater. Under this remedy the groundwater treatment goals can be achieved in approximately five years through the use of the effective cell units. The cap system of this remedy also includes phytoremediation capabilities which will further reduce contaminant flux into the adjacent surface water bodies. In contrast, Remedial Alternative 4, with a static pump-and-treat system, does not have the flexibility to respond to space-time changes of the groundwater plume.

6.1.6 Implementability

No implementation is required for the no action alternative. Remedial Alternative 4 is implementable; however, it is technically impracticable.

Remedial Alternatives 2 and 3 are implementable. Excavation of surficial soil and installation of phytoremediation/asphalt caps can be easily implemented using conventional equipment and standard construction. The phytoremediation cap in Alternative 3 can be changed to asphalt or buildings to maximize future site development.

The asphalt cap in Remedial Alternative 2 requires a stormwater detention basin which limits the implementability of future site development. Long-term care and maintenance of an asphalt cap system is also easily implemented using standard equipment and procedures.

6.1.7 Cost

The no action alternative has no direct cost. Indirect costs, such as the potential effect on property values or taxes associated with potential remedial actions, are not considered in this study.

The representative capital cost for Remedial Alternative 2A is $21,100,000 and the operation, maintenance and repair is $17,800,000. Engineering and non-contractor costs are estimated to be $2,800,000. The total present worth for the representative cost is $38,900,000. Tables 5-3, 5-4 and 5-5 summarize these costs for the representative costs for the Remedial Alternative 2 variations. The total present worth for the high cost scenario is $50,300,000. The high cost represents a sensitivity analysis and includes remediation of a higher volume of vadose zone soil and operation of treatment cells for 10 years instead of 5 years for the representative cost. Detailed cost estimates and assumptions are included in Appendix 5-C.

The representative capital cost for Remedial Alternative 3A is $14,100,000 and the operation, maintenance and repair is $10,900,000. Engineering and non-contractor costs are estimated to be $2,300,000. The total present worth for the representative cost is $25,000,000. Tables 5-6 and 5-7 summarize these costs for the representative costs for Alternatives 3A and 3B. The total present worth for the high cost scenario is $37,200,000. Detailed cost estimates and assumptions are included in Appendix 5-C.

The capital cost for Remedial Alternative 4 is $44,200,000 and the operation, maintenance and repair is $56,500,000. Engineering and non-contractor costs are estimated to be $3,000,000. The total present worth cost is $101,000,000. The estimated costs are based on a 50-year time horizon, which is inadequate for attaining Class I and MCL groundwater standards. Therefore, these costs should be viewed as under-estimated. Table 5-8 summarizes these costs. Detailed cost estimates and assumptions are included in Appendix 5-C.

6.1.8 State Acceptance

The evaluation of State acceptance is conducted in the Record of Decision.

6.1.9 Community Acceptance

The evaluation of community acceptance is conducted in the Record of Decision.

6.2 Conclusion

Based on the sevenevaluation criteria, Remedial Alternative 3 is the most cost-effective remedy, which consists of hot-spot removal and treatment; phytoremediation cap; and treatment-cell-based groundwater extraction, treatment, and reinjection. In summary, Remedial Alternative 1 is determined to be not sufficiently protective of human health and the environment. Remedial Alternative 4 is technically impracticable. The comparison of Remedial Alternatives 2 and 3 revealed that these alternatives provide equivalent protectiveness and compliance with ARARs. Alternative 2 and 3 are comparable in terms of long-term effectiveness, short-term effectiveness, and implementability. Alternative 3 provides more reduction of mobility through treatment with the phytoremediation cap. Alternative 3 is more cost effective than Alternative 2 and maximizes future site use. .

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